Compressed Air

A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. IX. NEW YORK, AUGUST, 1904. No. 6.

"Compressed Air,"

OR

THE COMPRESSED AIR MAGAZINE.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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A Development in the Western Mining Field.

In the mining operations of the Western States there is to-day a wonderful opportunity for the electrically-driven air compressor.

While the original methods were very crude, the development of mining machinery has been rapid and the mine owners have been quick to see the varied advantages which follow its adoption. With a full equipment of mining machinery, the question of power began to assume an importance not hitherto recognized. That old friend, the steam engine, was a costly visitor in many instances while valuable water-power was going to waste. Electric generators were the inevitable result and electric-driven mining machinery came forward with a rush in consequence.

The air compressor has long been an important adjunct for mining operations. While steam and occasionally water power was used to operate them, the extension of the long distance electric transmission lines has enabled the mine owner to secure power right at his mine at a cost heretofore thought impossible. The old and more costly method of operation is abandoned for the new, while the mine, which has heretofore lacked an air compressing plant, is able to install one and run it economically.

This new field, has, of course, brought forward many new problems which must be worked out as they present themselves. A paper on the subject of electrically-driven air compressors appears in this issue. It brings out some very interesting facts. While all our readers may not agree with every statement made, they will certainly read it with interest. We shall be pleased to give space to a discussion of the subject which may arise from any difference of opinion as to conditions or results.

Pneumatic Tube Service.

While compressed air has not been adopted as a power for the operation of street cars or other forms of public conveyances, it has made a field for itself in the transmission of letters and small packages. The pneumatic tube systems have really no successful rival. Though largely confined at first to stores and short lines, they are gradually being adapted with success to lines several miles in length. Several schemes have been advanced for

transporting mail for long distances in this way, but for one reason or another the installation has never actually been made. From the improvements in the tube systems and in the compression of air, it is reasonable to expect that these long distance lines will be a reality before many years go by. In the notes at the back of this number is one containing extracts from the annual report of one of the largest of the companies installing these systems. To those who have not followed the progress made along these lines the report of the recent installations made will be rather surprising.

Electrically-Driven Air Compressors Used in Mining Operations.

Almost from the very beginning of the long-distance transmission of power by electricity the electric motor has played an important part in the operation and development of mining properties and not the least among its various adaptations is its usefulness in driving air compressors.

Air compressors, in their turn, play an equally important part in the economical management of all good properties, and the use of compressed air has become so general that it is scarcely worth one's while to mention its various applications. Of course it goes without saying that rock drilling is its most useful applicability and is the one which, up to the present time, has not a worthy competitor. All manner of devices such as electric drills, gasoline drills and even steam have been used to supplant it, but in each case failure has been recorded. More success has attended the efforts to make a more direct application of power in such service as pumping, hoisting and ventilation, but even in these fields compressed air is still widely used.

Up to a very recent date almost anything in the way of an air compressor was good enough for the ordinary purposes of mining, just so long as it could be converted to a motor-driven machine. To-day, however, this sentiment has taken a decided turn for the better class of machinery, and it pleases me to state that some of our leading manufacturers have kept pace with this growing demand for better and more efficient compressors.

The requirements for a good electrically-driven air compressor for mining work are simplicity, reliability, ready applicability to a motor drive and economy under variations of load. The first is secured through the fewness of parts and lack of complication in the valve mechanism, reliability through substantial construction and ease of repairs, a reasonably high speed so that it may be belted or geared directly to a standard motor and it must be so arranged that it will operate ostensibly as a variable volume machine when driven at a constant speed. This last requirement is not fulfilled by the introduction of a simple unloading device, but must be accomplished by means of an automatic control of the intake valves. Many attempts have been made along these lines and some with considerable success, but the best and simplest device I've been able to find is the choking intake control recently placed on the market by the Ingersoll-Sergeant people. With this the machine is carefully unloaded in an automatic way and the power economically used during such time as the maximum capacity of the compressor is not in demand.

We have recently installed three Ingersoll-Sergeant compressors on the Comstock and the results are all that could be desired. One, a 10¾-inch by 12-inch Class B straight line, single-stage machine. is installed on the 1,200-foot level of the Caledonia Mine at Gold Hill. This is belted directly onto a 30 H. P. General Electric Induction Motor and is used exclusively for running rock drills. An 18¼-inch and 12¼-inch by 12-inch Class "J C" Compound is in place at the Union Shaft. This is driven by means of a 75 H. P. Westinghouse Induction Motor mounted on a common bed-plate and connected with the compressor by means of a Morse silent chain drive. The third one is for the Ward Shaft. It is a 19¼-inch and 11¼-inch by 14-inch Class "D C" Compound machine and is belted to a 100 H. P. Westinghouse Induction Motor. This last-mentioned machine will be used to operate rock drills and possibly an air lift during our preliminary pumping operations.

We have numerous other belt-driven machines at the various mines, but they are either old steam-driven compressors fitted up for a motor drive or are compounds of an antiquated design so that I have neglected to go into detail regarding them. Our experience has dictated that the best two-stage variable volume air compressor is the most economical for use where the power bill is an object and we can conscientiously recommend no other.

LEON M. HALL,
Consulting Engineer.

[Since this article was written the plant of the Union Shaft referred to has been destroyed by fire, but steps are now being taken to replace it.—*Ed.*]

The Electrically-Driven Compressor Plant of the Fremont Consolidated Mining Company.

The Fremont Consolidated Mining Company, of Drytown, Cal., has installed an electrically-driven air-compressing plant which is giving perfect satisfaction. The machinery is located in an iron-clad building specially constructed for the purpose. The compressor is an Ingersoll-Sergeant duplex rope-driven Class "D" machine, with air cylinders 20¼ inches in diameter and a stroke of 24 inches. At a speed of 96 R. P. M. the free air capacity is 1,360 cubic feet per minute and the working pressure is 70 to 75 pounds on the lines. The compressor is equipped with a standard air regulator which is set at 80 pounds pressure and is sensitive within 2 pounds. The driving wheel of the machine is 18 feet in diameter and grooved for sixteen ropes 1¼ inches in diameter.

The motor is of the General Electric Induction type, designed for 550 volts and rated at 300 H. P. Its actual speed under full load is 498 R. P. M. The motor pulley is grooved for seventeen 1¼-inch ropes. The motor is equipped with an automatic oil switch and starting resistance. Current for operating the plant is secured from the lines of the California Gas and Electric Corporation.

Compressor and motor are mounted on ample concrete foundations, with rope centres of 40 feet. The rope drive is of the continuous system, and tension is maintained by a tension sheave on an overhead carriage.

Unusually large receiver capacity is provided, there being six 54-inch by 16-feet receivers mounted in battery outside the power house, equipped with gauges, drain cocks and safety valves set at 100 pounds pressure.

Air from the compressor plant is used for a variety of purposes in and about the mines. Some of the uses to which it is put are driving rock drills, pumps, hoisting engines, an amalgam press, and for blacksmith forges, starting oil burners, clearing electric motors, operating a gasoline assay furnace, and an air lift for fire protection. For hoisting, the air is used only as an auxiliary to a steam plant, and by its use considerable fuel is saved at times when only light and intermittent hoisting is to be done.

The plant throughout is running smoothly and requires but little attention in operation.

ARTHUR GOODALL,
Chief Engineer.

Electrically-Driven Air Compressors for Metal Mining Purposes.

The modern tendency toward consolidation of rival interests for mutual benefit is extending into the fields of applied mechanics, and a noteworthy instance is seen in the amicable co-operation with which electricity and compressed air, the one-time rivals, have joined forces to meet the difficulties encountered in the mining field, where formerly the latter held undisputed sway.

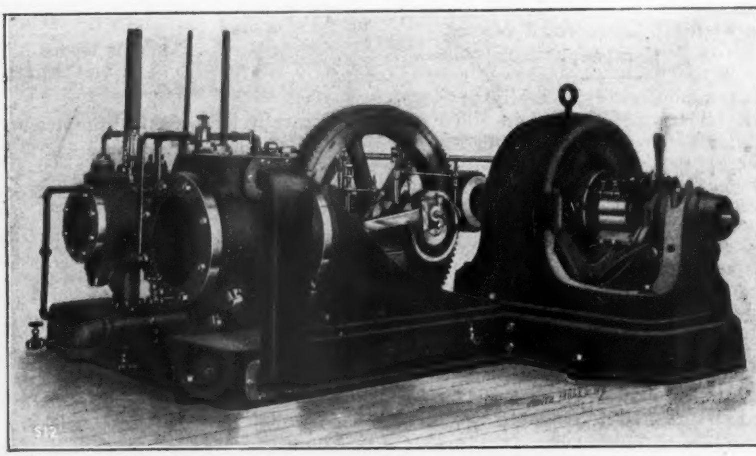
The "bonanza days" of mining are passed—the days when fabulously rich veins made great fortunes in a moment, the days when operating economies were ignored in the huge profit yielded by high-grade ores. Time has demonstrated the fallacy of the old-time doctrine that "mines grow richer with their depth." Rather has the reverse been found to be the case, for as workings go deeper, the small but rich veins give place to large bodies of low-grade ore. To-day five, ten, twenty, fifty tons of ore must be mined, trammed, hoisted and treated, to yield the value of one ton of the ore of the earlier days. Cost of hoisting and tramming has increased with the depth and extent of the workings. Diminishing ore values, with increasing tonnage to be handled and increasing expense of handling and treating, have brought mining enterprises to a "low-grade basis" and necessitated

the adoption of the best business principles and methods. Operating and productive costs must be reduced to the smallest value.

The above is in outline the history of most of the old "treasure troves" of the mining districts. Another result arising from the working out of old bonanzas is that attention has been turned to other properties, ignored in the richer days, but in themselves valuable if operated on close economy by modern business methods. In these newer mines much the same conditions exist; large bodies of low-grade ore requiring to be handled and treated in quantity and at small cost, to yield a profit. But whether the enterprise be new or old, the mind of the progressive manager turns first of all to the question of power—its production, its cost and its application.

With the first two factors in this question, the present paper has nothing to do. They are assumed to have been settled by the presence at the mine of electric power in available form. These notes have to deal only with the matter of applying this power, or converting it to another form. But it may be interesting to sketch briefly at this point the field as it is, and into which the electrically-driven air compressor has come, bringing cheer to the heart of the perplexed manager.

A peculiarly discouraging situation faces him. Mining districts are usually remote from sources of cheap fuel. Rarely has Nature placed coal and ore deposits close together. The mines themselves are in inaccessible gulches, or high on the mountain side. Coal can be delivered at the shaft only at great expense, after a long and difficult haul. The timber on the hills has probably been removed, wholly or in part, in the earlier workings; no boiler water is available, except the acid-charged accumulation in the mine sump. The balance of conditions is somewhat thus: on the one hand, a large body of low-grade ore to be mined and treated at minimum cost; on the other hand, excessive cost of power, and consequently of all operations dependent thereon.



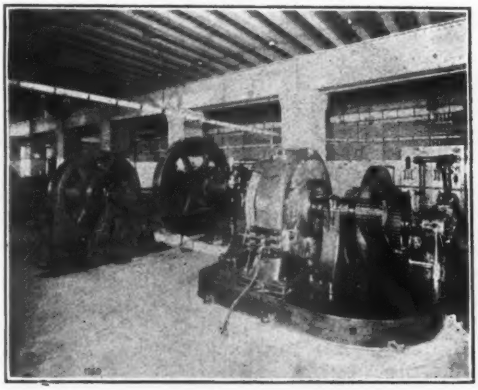
INGERSOLL-SERGEANT CLASS "J C" AIR COMPRESSOR, GEAR DRIVEN BY ELECTRIC MOTOR.

The conditions described are not exaggerated. A few examples from the writer's experience may, however, strengthen the argument. In one of the oldest and best-known mining districts of Colorado a personal canvass of over sixty mines showed the cost of coal at the shaft ranging between $9 and $16 per ton, and poor lignite at that; while the power

used was costing from $190 to $216 per horse-power per year. In a well-known and prosperous district in Utah, the price of coal at the shaft averaged over $10 per ton, and the power for two eight-hour shifts was ranging in cost from $128 to $212 per horse-power per year. Many of these are large mines with huge plants and up-to-date equipment. One of the largest properties was paying $300 per year per horse-power, in days of twenty-four hours.

Into the field of which the above are typical examples, the electric power transmission systems are extending their slender antennæ, placing at the mine shaft, almost, electric power in quantity ample for every need, at prices defying local competition, and infusing new life and hope in districts borne down under the load of excessive power costs. Usually these transmission lines come from the huge generating stations of one independent company controlling the water rights of a number of streams. Sometimes a number of mining companies combine to develop a distant water power and deliver its energy at their several properties. Whatever the source, the problem confronting the mine manager and engineer is that of most advantageously applying the electric power to the varied demands of mining operations. It is not within the province of this article to deal with the questions of tramming, hoisting, pumping or milling by electric power. Each of these is a subject meriting individual treatment. The present paper is intended as a discussion of the problems entering into air compression by electric power. In all that follows, it must be borne in mind that the highest operating economy is the object sought, implying a reasonable investment justified by subsequent reductions in expense.

Mine development is dependent upon the amount of rock broken, and this, in turn, dependent upon the drills used and the work they do. All claims to the contrary notwithstanding, the electric drill, in its present state of development, cannot be considered as a legitimate factor in mining operations. The air drill is the main dependence of the miner, and so long as this is true compressed air must be furnished to run it. It is also, perhaps, an open question as to whether compressed air is not a more satisfactory and economical agent than electricity for operating mine hoists and pumps. But this interesting point cannot be discussed here. In any case, compressed air is required and the problem reduces itself to the best

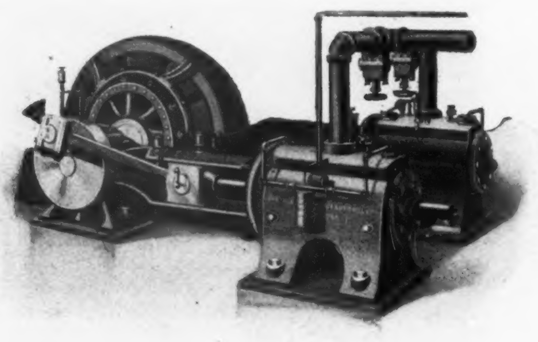


INGERSOLL-SERGEANT CLASS "J C" COMPRESSOR, SILENT CHAIN DRIVEN BY ELECTRIC MOTOR.

method of compressing air by electric power.

The selection of the compressor itself is naturally the first point to be considered. Operative economy is the end sought, and much of this is dependent upon the efficiency of the compressor. A number of factors enter into compressor efficiency; the machine structure must be strong, that strains may not produce undue friction; bearings must be large and long; valve area must be ample and free; valves must open and close at just the right time, with the minimum of power required in operating them; cylinder clearance must be as small as possible; ample provision must be made for cooling; cylinder heads and barrels must be jacketed, and if the compressor is compounded, ample intercooling capacity must be provided; two stage compression should be used for pressures above 80 pounds.

Other fundamental requirements should be strength and simplicity; for repair facilities are rarely at hand, and skilled labor is conspicuous by its absence in the average mining camp. The selection of type is an important point. For comparatively small plants, the straight-line compressor has many advantages which recommend it. It is usually devoid of unnecessary complications. It is self-contained, and its strains are well distributed in the machine structure. It does not require elaborate or expensive foundations. On the other hand, the power-driven straight-line machine is not all that it should be, in that its two compressions per revolution give wide fluctuations in belt tension and strain upon the driving motor. A heavy belt fly-wheel may somewhat mitigate this evil. The duplex cross-compound type of compressor is largely free from this objection. Its cranks at 90 degrees give four compressions per revolution, equalizing the shocks, minimizing the strains, and giving smooth running—a condition easier on compressor, motor and connection. While heavy motor armatures rotating at high speed have in themselves considerable fly-wheel effect, it is a decided advantage, even with the duplex type, to have a heavy fly-wheel on the compressor.



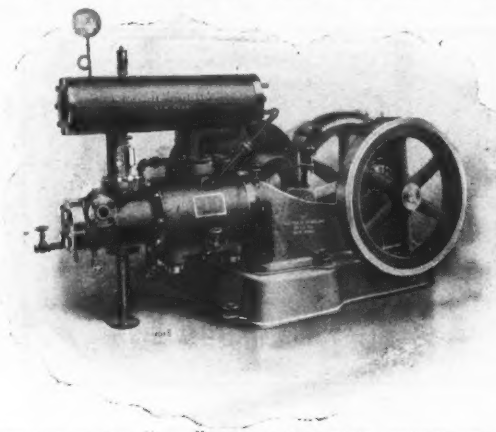
INGERSOLL-SERGEANT CLASS "D" AIR COMPRESSOR, DIRECT CONNECTED TO ELECTRIC MOTOR.

It must be borne in mind, in the selection of a compressor for electric drive, that no overload capacity can be depended upon; *i. e.*, an overload of volume or piston displacement. It is common practice—though by no means good practice—in small mining plants where a steam-driven compressor is used, to speed up the machine when extensions of work call for an added drill or two. This is a very poor policy, for the maker's rated speed is usually the limit of endurance under continued service. Such a procedure is manifestly impossible with a constant speed electrically-driven compressor, and a machine must be installed at the outset giving the maximum required capacity at normal running speed. In planning the electrical compressor plant, therefore,

provision must be made for a fair margin if any increase is contemplated. This margin should be made as small as possible, that the unit may run as near as possible to full-load efficiency. Future additions, of any magnitude, to the drill equipment will then call for an added unit, leading naturally to the system of sub-divided power now to be discussed.

The proper sub-division of the compressor plant is one of the most vital factors in economical operation; for high economy demands that the plant as a whole be operated all the time as close as possible to the point of maximum efficiency. This means, in an electrical compressor plant, that full load be carried. This is evidently impossible if a single large unit is installed, and the best way out of the difficulty lies in the installation of several compressor units, in number and capacity determined by the maximum required capacity and the operating conditions of the mine. Each of these units will be independent, but capable of supplying in parallel with the others to a common centre of distribution. As the load curve rises and falls during the working day, units will be added or cut out, the load on each individual remaining fairly constant and close to the maximum rating. This may be to many a new doctrine in mining questions. But it has long been recognized in power generating stations and has the same advantage in power conversion. It seems an easy and pleasing way of solving the perplexities of mine operative economy. As a matter of fact, the problem involves a number of distinct and often opposing features, demanding acute engineering perception, wide experience and mature judgment. To lay out a system of mine operation which shall give a daily load curve with variations, wide perhaps, but well defined and recurring at known intervals, calls for an intimate knowledge of mining methods, and organizing ability of a high order. No fixed rules can be laid down, or followed if laid down. Such an article as this can only suggest.

It rarely pays to install a motor driven compressor smaller than 35 H. P.; in fact, this is about the size of unit required to drive one 3½-inch drill at 9,000 feet altitude, with air at 100 pounds pressure, after making fair allowances for losses in conversion and transmission. A unit to drive three drills of the same size under the same conditions, making allowance for loss in the same ratio, will require a 100 H. P. motor. A 5- drill plant would, at first thought, be expected to require a 175 H. P. motor. But, owing to the time lost in changing steels, moving drills, etc., experience has shown that a 150 H. P. motor will take care of the load. At this point it may be well to state that ample receiver capacity is a most essential feature in electrical compressor plants, in absorbing fluctuations and in bridging over momentary overloads. Assume that a mine system is so laid out that five drills are run on the day shift, while one is

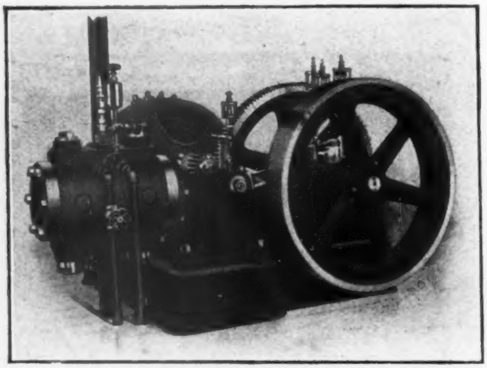


INGERSOLL-SERGEANT CLASS "E C" AIR COMPRESSOR, GEARED TO ELECTRIC MOTOR.

run on the night shift in cross-cutting or development work. If the compressor plant consists of one unit driven by a 150 H. P. motor, this motor will run during the day at full load and highest efficiency, while at night it will carry less than one-quarter load, with an efficiency corresponding to that load. However, if two compressors are installed, one driven by a 100 H. P. motor, the other by one of 50 H. P., both will operate during the day at maximum efficiency, while at night the larger can be shut down, the smaller one then carrying the night load at efficiency corresponding to a trifle less than three-quarter load. This is a hypothetical case. Perhaps in practice the lines would not be drawn so fine on so small a plant, though there is little doubt that it would well repay the small added investment. But the example serves to illustrate the principle. Similarly, a 500 H. P. plant might be profitably divided into two units of 200 H. P., one of 100 H. P. A plant of 1,000 H. P. might consist of two 500 H. P. units, or perhaps higher economy might be secured from one 500 H. P., two 200 H. P. and one 100 H. P. The advantage of units of uniform size should, however, be kept in mind—interchangeability of parts, making more effective a comparatively small stock of duplicate parts. However large the plant, it is never advisable to exceed 1,000 H. P. in a single unit. Local conditions—extent of the property, nature of load, system of operation, etc.—must in every case be made the subject of careful study before a plant can be so designed as to ensure the maximum operating economy. The solution of the problem lies only in the proper application of recognized principles of engineering.

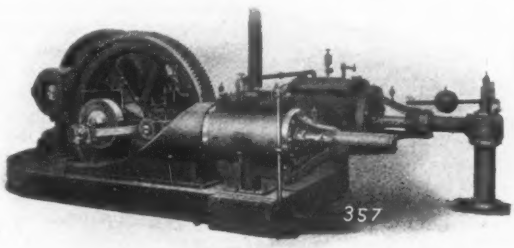
The electric current for power may take one of two forms—direct or alternating. Since only mining plants are to be considered, in almost every case supplied from transmission systems demanding the use of the alternating current, direct current machines may be dismissed with a brief mention. The direct current motor has no features of peculiar advantage in the mining compressor plant. It may be operated at variable speeds, but with poor economy at any speed but the normal. The modern unloading or regulating devices for air compressors make a variation of speed unnecessary. The direct current motor may build up its load with its speed by the use of suitable starting devices, but this is of questionable advantage in mining compressor work. But should direct current—and only that—be available, the methods of connection between motor and compressor, and the systems of regulation, will be the same as for alternating current plants and will be discussed later.

The alternating current motor is available in two distinct types — the synchronous motor and the induction motor. It is unnecessary here to consider the



INGERSOLL-SERGEANT CLASS "E" AIR COMPRESSOR, GEARED TO ELECTRIC MOTOR.

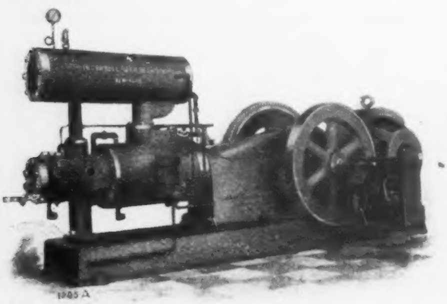
further classifications into single, two and three phase types. The synchronous motor for driving air compressors is open to many objections. Perhaps the least vital of these is that it will not start under load—a demand very seldom made upon a mining compressor in any case. Even when thrown in parallel with a second fully loaded machine, suitable unloading starters allow it to be brought up to speed before assuming its load. The synchronous motor requires some source of direct current to excite its field. It is not self-starting and must be brought up to full speed by some separate source of power before any load is thrown upon it. Once up to speed, it is essentially a constant speed machine, and will maintain its speed regardless of load, within the limit of its power capacity. Should a sudden overload occur—due, say, to the failure of an unloader simultaneously with the sticking of a relief valve—the synchronous motor drops out of step and stops. Claims are made for this machine that it has no inductive effect on the line—that its power factor is unity. This is true only when its field is properly adjusted to its load. Any variation in the load will cause the current to lag or lead, and the power factor will vary accordingly. Could the motor field be varied automatically with the load, the power factor might be maintained at unit value. But at the present time the varying load of a mining air compressor is not successfully handled by the synchronous motor. Generally speaking, this motor has no place in the mining compressor plant. But a hypothetical case mav be outlined which is a conspicuous exception to the rule. Let it be supposed that a mining company controls a water-power capable of delivering 1,000 H. P. at the mine during eight months of the year. During the remaining four months low water reduces this available energy to 600 H. P. But 1,000 H. P. is demanded continuously at the mine for compressing, hoisting, pumping, milling and lighting. Of this total amount 200 H. P. is required by the compressor plant. Coal is available but expensive, and full advantage is to be taken of the water-power. In this case a 200 H. P. cross compound or duplex compressor would be installed, coupled direct in tandem to a 400 H. P. cross compound Corliss engine, with a 200 H. P. synchronous motor direct connected or belted. During eight months the engine would be uncoupled and the motor would drive the compressor with current from the distant water-power. During the remaining four months the engine would be coupled up, driving the 200 H. P. compressor and the synchronous motor as a generator, delivering 200 H. P. of electrical energy to the system, and maintaining the required maximum of 1,000 H. P. This is an example of the one instance where the synchronous motor, in virtue of its reversible feature, has a place in the mining compressor plant. Except in such cases it is suitable only for large units at uniform load and constant speed.



INGERSOLL-SERGEANT CLASS "J C" AIR COMPRESSOR, GEARED TO ELECTRIC MOTOR.

The induction motor, on the other hand, has features of peculiar advantage in mine compressor work. It is self-starting, but an undesirable feature is, that started under full load, it may require current seven or eight times that required at normal running—a sudden inrush which may have a serious inductive effect on the line. But as stated above, the instances where it is necessary to start

under load are very rare. Under normal conditions, if the starting torque is not required to be too much greater than the running torque, a properly designed induction motor will start with a current but very little in excess of its running current. The machine may be overloaded to a standstill without burning out or other injury. Its speed is practically constant, seldom varying more than 5 per cent. from the normal. As load increases upon it, it will slow down very slightly until the currents induced in the rotor by the "slip" are sufficient to carry the load. It is self-governing and has a high efficiency even at fractional loads. Its sturdy structure and the absence of delicate parts liable to derangement make it peculiarly the motor for heavy continuous



INGERSOLL-SERGEANT CLASS "E C" AIR COMPRESSOR, SILENT CHAIN DRIVEN BY ELECTRIC MOTOR.

service in unskilled hands and in regions remote from repair facilities.

The method of drive, or the connection between motor and compressor, is another link in the chain of economies, offering interesting engineering problems when low operating cost is a fundamental. A choice of five different methods is offered, though sometimes local conditions reduce the number; direct connection, direct gearing, belt drive, rope drive and silent chain drive. They will be discussed in order, with their characteristics and limitations.

Direct connection—the motor driving the compressor by a shaft common to both—has, so far as the writer knows, never been employed in mining practice, though successfully used in industrial plants. But there seem to be no legitimate objections to it, aside from considerations of first cost. When the size of the unit justifies it, and the motor speed can be made that of the compressor, this method would seem to be the ideal solution of the problem of drive. Such a slow-speed motor would have a rotor very large in diameter and very heavy, which would serve all the purposes of a heavy fly-wheel. The unit would be compact and self-contained, and the mechanical efficiency would be higher than that secured by any other method of drive. The expense of a heavy belt or rope drive saved by this means would in large powers materially offset the greater cost of the slow-speed motor. The heavy belt fly-wheel on the compressor would be dispensed with—another offsetting item. For large and permanent compressor plants, the direct-connected unit would certainly have all the advantages of the direct-connected generating set, so widely acknowledged in the engineering world. Interesting developments certainly lie along these lines of electrical compressor practice.

Direct gear connection finds its best field in those instances where floor space is limited and a suitable distance between rope or belt centres cannot be secured. Any speed reduction may be secured by proper gear ratios between motor and compressor. The motor should be mounted upon the extended sub-base of the compressor, or otherwise made an integral part of the unit. Ample fly-wheel effect must be provided, either in the compressor gear itself or in a separate wheel on the compressor shaft. Direct gear drive is open to the objections of noise and inefficiency. The first evil may be diminished by the use of raw-hide pinions. Carefully cut gears, proper alignment, rigid mounting and copious lubrication may reduce the second objection. A properly designed gear drive should give a mechanical efficiency ranging between 90 and 95 per cent. It is well to remember that gear efficiency is higher, the higher the velocity of the pitch line, and gear drives should be designed with this in mind. A slight cutting reduces the efficiency very rapidly, suggesting the value of protecting the gears. If, as is too often the case, the compressor unit is located close to a rock-crushing plant, some effective means must be provided for protecting the gears from the flying quartz powder, which approaches emery powder in its grinding action on gear

teeth. It is impossible to fix any definite maximum beyond which gear drive should not be used. But in large sizes there certainly is a point beyond which direct connection has advantages far beyond those of gearing.

Belt drive is of course the method most commonly used. There is no limit to the extent of its application. Properly designed, a belt-driven unit may have an efficiency ranging between 85 and 92 per cent. Here again there is a certain speed at which maximum economy is secured and this critical belt speed should be borne in mind in proportioning the pulleys. A peculiarity of the mining plant is that floor space is often secured only at the expense of a heavy cut and fill, resulting in a tendency to cramp the unit and bring belt centres closer than good engineering suggests. As a consequence of this tendency, short belt centres, high belt tensions and excessive journal friction is too often the rule, and a lowered transmission efficiency is the inevitable result. A fairly safe rule to follow in this connection is to make belt centres not less than two and one-half or three times the diameter of the driven pulley. The distance from centre to centre of shafts should be great enough to permit the sag of a comparatively slack belt to give the requisite contact and pulling power without undue side friction in bearings. On the other hand, too long centres give a long, noisy, flapping belt. Idler pulleys and belt tighteners should be looked upon as mere make-shifts and avoided wherever possible. It is perhaps needless to say that the direction of motion of the belt should be from the top of the motor pulley to the top of the compressor pulley, that the sag may increase the arc of contact. It may be equally unnecessary to remark that vertical belts should be avoided and that 45 degrees is about the maximum angle which the lower belt side should make with the horizontal. Yet violations of these rules are not at all uncommon in mining practice.

Rope drive has many features of peculiar interest in mining compressor work. Rope is cheaper than belting. In powers below 250 H. P. the total cost of rope and belt drive is about the same, for though rope is cheaper, rope sheaves are more expensive. But in powers above this the cost of a rope drive will be from 75 to 60 per cent. that of an equivalent belt drive—the percentage decreasing as power increases. A rope drive is positive —the slip is practically negligible. It will operate economically on very short centres, and without undue tension and bearing friction. It is a strong, rugged construction and stands abuse somewhat better than a belt drive will. The liability to breakage is less, because of the fact that the strain is distributed over a number of members. A rope drive properly designed and maintained should have a mechanical efficiency of from 87 to 95 per cent. Careful attention should be given to securing the proper shape of groove in the sheaves. It should be unnecessary to say that regular transmission rope should be used instead of common rope. Yet many people do not know the difference. A transmission rope should have a life from two to three times that of ordinary rope in transmission work. The choice between the various "systems" of rope drive must be left to the judgment and taste of the engineer.

The silent chain is a comparative newcomer in the transmission field, yet its forward strides are awakening the keenest interest. This method of drive gives an efficiency higher than any other except direct connection—it has repeatedly sustained an economy of over 99 per cent., and this figure should not be impossible to attain in a properly designed compressor unit. Chain drive fills the gap between gearing on the one hand, and rope or belt drive on the other. It is positive in its action—has no slip. It has no minimum limit of centres. Its action is independent of arcs of contact. But it is a question whether it is the proper agent to use in powers above 200 or 250 H. P. It has not yet been satisfactorily tested in larger powers. However, below the limit mentioned it has made a good record for simplicity, compactness, reliability and efficiency. These features recommend it to the careful consideration of the engineer seeking operative economy. The same care as to alignment, lubrication and protection should be given this drive as was mentioned above in connection with gearing. A common subbase should unite motor and compressor. The silent chain drive has demonstrated its reliability in compressor work under most severe conditions, notably in the high-pressure Ingersoll-Sergeant compressors furnishing air for the storage brake system of the St. Louis Transit

Company, and for the switch and signal system of the New York subway.

The proper and efficient control and regulation of the electrical compressor plant is secondary in importance only to the judicious selection and arrangement of the plant itself. Every cubic foot of air blown off through a relief valve represents so much wasted power. The modern plant demands a regulator which automatically proportions the amount of current consumed to the volume of air compressed—or more correctly speaking, the regulator must proportion the volume of air compressed to the amount of air demanded, since the self-governing features of the motor itself will adjust the current consumption to the work done in compression. As stated earlier, the electrical compressor has no overload displacement capacity. But it may have an overload of pressure and it is the function of the regulator to prevent this by never allowing air pressure to exceed a certain fixed maximum. Maximum displacement capacity must be always available, yet fractional loads must be economically handled by the unit system and the automatic regulators. The layout of mine work should be such that load fluctuations greater than the capacity of a single unit will occur at regular known intervals, and will be provided for by varying the number of active units at these stated times. The function of the regulators is to economically control load fluctuations of magnitude less than a unit's capacity. It must be remembered that variations of load in an electrical compressor plant are equally distributed among the active units feeding to a common centre, or receiver. In other words, if three induction motor-driven units are active, two will not be fully loaded and the third only partially, but each will carry one-third the total load. This means that each unit must have its individual regulator—it also means that in a multiple unit plant the requirements on each regulator will be only moderate. As stated above, the regulator must proportion the volume of air compressed to the volume demanded—an end which can only be secured by varying the displacement capacity of the compressor. Evidently this cannot be brought about, as in a steam-driven compressor, by a variation in speed and piston displacement, since the electrical compressor is a constant speed machine. The only alternative is to make a portion of the piston displacement ineffective, this portion varying with the load. There are several methods of attaining this end, but in all of them the operative force is air pressure, acting on a regulator piston, and opposed by the action of weights adjusted to a predetermined effect. In one device, excess pressure opens a communication between the intercooler of a two-stage compressor and the atmosphere, thus partially unloading the low-pressure piston and making the high pressure an ordinary single stage compressing cylinder. This is only a partial solution of the problem. The air compressed in the low-pressure cylinder and discharged to atmosphere is wasted. The high-pressure cylinder operates at the lower efficiency of single stage compression. Another and more effective form of "unloader" is one in which excess pressure above normal causes one or several of the discharge valves at each end of the cylinder to be opened and be held open, thus admitting pressure to both sides of the piston. The inlet valves remain tightly closed under this pressure and, the piston traveling under balanced pressures, power is consumed only in overcoming the friction load of the unit. In two-stage compressors the device may be applied to both cylinders, unloading both of them. When receiver pressure falls to normal, the weights restore compressing conditions. This device, while perfectly effective as an unloader, is open to the very decided objection that its action is so positive and sudden that heavy strains at loading and unloading are thrown upon the entire structure of the unit, which in machines of large size may have serious results. It should never be used on units of more than 100 H. P. A third form of regulator is free from the above objection, because its action is made gradual by the presence of an oil-damping device. It is suitable for compressors of any capacity and operates successfully under heaviest fluctuations. It is known as the "choking controller" and is the product of the Ingersoll-Sergeant Drill Company. In its essentials it is a multi-ported piston valve introduced in the intake conduit of the compressor. Under normal conditions weights hold this valve at full opening, leaving an unobstructed passage for the intake air. As pressure rises above normal it acts on the controller piston to lift the valve and throttle the intake passage, wholly or in part, according to the duration of the over-

load. The damping device makes the movement of the valve slow and all shocks and strains are avoided. As the valve closes, the volume of air drawn into the intake cylinder and there compressed is gradually reduced. The action of the controller is communicated to the high-pressure cylinder of two-stage machines in the reduced volume delivered to the intercooler. With the valve fully closed, both pistons travel *in vacuo* and only the friction load of the unit remains. The restoration of normal pressure allows the controller weight to slowly fall, and the compressor gradually resumes its load. It is to be noted that this controller is not adaptable to high pressures—say above 150 pounds in two-stage compression. For as the intake air with the unloader in operation is rarified and at about normal temperature on entering the cylinders, its compression to a high pressure may run the temperature up to a destructive value, since heat of compression is a function of the number of compressions.

A plant properly subdivided and managed, and equipped with regulators as above described, should require in operation no attention beyond proper lubrication and the varying of the number of active units with fluctuating loads. But provision must be made for starting. As stated earlier, where synchronous motors are used, it is impossible to start under load. With induction motors it is not advisable to do so, because of the heavy inrush of starting current and its effect upon the line. Some means, therefore, must be provided for unloading the compressor at starting. If the machines are equipped with regulators of the first or third class described above, they may be unloaded by lifting the regulator weights by hand and holding them there until the unit is up to speed. If the regulator is of the second class, and air pressure is on the receiver from another source, the same operation will unload the unit until it is up to speed. An electrical starting device might be arranged, similar in every way to the regulator of the second class above, except that one or more of the discharge valves at each end of the cylinder would be opened by the current in a solenoid, controlled through a switch near the motor starting switch. Then when normal speed is attained, the switch would be opened, the valves would close, and compression would begin. By a similar arrangement, the valve of the regulator of the third class might be closed by the action of a solenoid and opened by a switch under the attendant's hand. As electrical compressor practice extends doubtless the electric current will be found useful as an auxiliary in many ways not at present imagined.

The modern air compressor is a sturdy machine. It has been weighed in the balance and not found wanting. Years of severe service have shown it to be a machine to be relied upon. Its very strength and vigor have laid it open to abuse at the hands of careless or unskilled attendants, and nowhere is its unfailing good nature more likely to be imposed upon than in the average mine plant. The electrically driven compressor unit has not lost any of this native vigor; it has inherited the family strength. But it is the latest product of modern engineering refinement, and perhaps repays attention with an appreciation keener than that of its steam-driven forefather. The alternating current motor of to-day—particularly the induction motor—is as nearly "fool-proof" as a piece of high-grade machinery can be. Yet even it resents an accumulation of mill dust, or a neglect to oil it properly. Throughout an electrical compressor unit only the best oils should be used—and good oiling does not mean flooding. The compressor plant should be located as far as possible from a crushing mill, and if a safe distance cannot be reached, a tightly closed room should be provided for the machines. Experience has shown that machine bearings wear quite rapidly enough without the assistance of quartz powder as an abrasive. Gears and chain drives could further with profit be wholly enclosed in dust-proof shields. Intake air should be drawn through a conduit from the coolest place, and if the air is filled with dust some means must be provided for eliminating it. A simple and effective "air washer" consists of a nest of tubes through which the air passes, sufficient in number to give ample passage way, and set vertically in a box with their lower ends immersed a few inches in water. The air, drawn downward through the tubes and bubbling up through the water, leaves in the latter its solid matter. Needless to say, the water should be changed frequently. If a continuous flow through the box can be secured, so much the better. Beside preventing scouring of the air cylinders by

the grit in the air, this device will be further effective as an economizer, if the water is cool enough, by lowering the intake air temperature and increasing the efficiency of compression. An ample flow of cooling water must be secured for jackets and intercoolers. If a supply already provided for other purposes is not at hand, a tank may be erected and supplied by a small motor-driven pump, drawing water from a suitable source. Or, better, an air-driven supply pump might fill the tank at times of light load, to a small extent filling a depression in the daily load curve. Before mine water is used, it should be analyzed to detect the presence of any acids destructive to intercooler tubes.

In closing, it may be said that the design and operation of a successful electrically-driven compressor plant for mining purposes offers no difficulties which cannot be met by the application of recognized principles of mechanical and electrical engineering. The modern mine is a "business proposition." In the foregoing pages this fact has been kept constantly in view and the recommendations are based thereon. It has been assumed from the first that the mine manager is seeking the same close economy which characterizes other present-day productive enterprise—an economy which often marks the difference between dividends and receiverships. The electrical air compressor is to be one of the greatest factors in the development of the huge low-grade ore bodies of the world. Its usefulness in these fields is only beginning to be realized. It has not yet received the recognition it deserves.

LUCIUS I. WIGHTMAN, E. E.

Caisson Illness and Divers' Palsy; An Experimental Study.—Continued from COMPRESSED AIR, July, 1904.

Three rats exposed to 5½ to 6½ atm. survived rapid decompression, while two at 8 atm. died.

Seven rabbits at 6½ atm. survived rapid decompression.

The most striking of Bert's results is the following: A dog was put at 9½ atm. The apparatus burst. The dog instantly died. Enormous subcutaneous emphysema was found, with gas in stomach, omentum, anterior chamber of eye, cerebro-spinal fluid and spinal cord. The right heart was full of gas, which, on analysis, yielded 15.2 per cent. CO_2, 82.8 per cent N_2, and 2.0 per cent. O_2.

Having observed the effect of rapid decompression, Bert found that dogs may be safely exposed to + 10 atm. if 1 to 1½ hours be taken for decompression. The animals must, of course, not be exposed too long, or oxygen poisoning will result.

G. Thompson compressed monkeys, cats, dogs, and pigeons to + 4 to 4½ atm. of oxygen or air for 1½ hours; there were no symptoms unless the decompression were too rapid. A dog stood a pressure of + 8 atm. for some time without discomfort. He then had a slight convulsion, but was all right after decompression.

Hersent exposed seven dogs to + 5 atm. for a few hours and decompressed them in 1 hour to 1 hour 15 minutes.

No symptoms resulted 18 times. Slight paralysis of the legs occurred four times. Paraplegia, cured in five days, occurred once. Death with gas in the heart resulted once. One dog decompressed in 50 seconds died. Two dogs decompressed in 15 minutes had paraplegia, and one died.

Hersent also exposed dogs to + 3 to 3.8 atm. for times varying from 11 minutes to 4 hours 11 minutes. The decompression lasted only 30 seconds to 50 seconds.

Out of nine exposures, there occurred two cases of severe paralysis and death with bubbles in the spinal vessels, and two cases of temporary paralysis of the legs. All these experiments show the frightful risks of rapid decompression and that even one hour for decompression is not quite sufficient for a four hours' shift at + 5 atm.

Hersent exposed a man to + 5.4 atm. for one hour and decompressed him in three hours. Itching and "bends" were not prevented, but no serious illness resulted.

The following preliminary experiments were carried out by one of us (L. H.):

(1) Two large toads compressed for one hour in 20 atm. O_2 and rapidly decompressed. The animals went into tetanic spasms, and swelled to double their size with the gas set free in their tissues. The heart was enormously distended, tense and scarlet in color. On letting out the froth it began to beat vigorously.

(2) Toad in 20 atm. O_2 for 5 minutes. Decompressed in 1 minute. There was some temporary paralysis of the legs and inertness. The animal soon recovered and hopped away into a corner. The same toad was placed in 20 atm. O_2 for 35 minutes. After rapid decompression it was found alive, breathing and trying to escape. In about 1 minute there followed tetanic spasms and rigidity of the legs. The heart was enormously distended, immobile, scarlet and tense. On letting out the froth it began to beat. Gas bubbles were seen in the walls of the intestine, in the lymph spaces, in the anterior chamber of the eye, in the pial vessels, etc. The lungs were enormously distended. The nerves and muscles were excitable, and the muscles contracted vigorously.

(3) Rat raised to 15 atm. O_2 in 4 minutes, then rapidly decompressed. The rat violently cleaned its face, there was tremor and tendency to spasm. The animal remained dull and inert, but recovered next day.

(4) Rat in 20 atm. O_2 for 6 minutes. Rapid decompression. Respiration almost failed, tendency to tetanic spasms, paralysis of hind legs, contracted pupils, died in 80 minutes. Air bubbles were found in the liver, mesenteric vessels, numberless small ones in the mesenteric fat in the uterus and foetal membranes (the rat was pregnant). The spleen and intestines were greatly congested. There was almost no blood in the heart. No naked eye hemorrhages in the C. N. S.

(5) Rat to 20 atm. O_2 in 5 minutes. Decompression to 7 atm. in 10 minutes and to O rapidly. Immediate convulsions, eyeball projecting, tetinal hemorrhages seen with ophthalmoscope, died in 10 minutes. Froth in the heart, and bubbles in the intestinal vessels and walls. No naked eye hemorrhages in C. N. S.

(6) Rat in 20 atm. O_2 for 2 minutes. Decompression in 1 minute. Rapidly cleaned face, dazed condition, a touch caused a violent jump like in first stage of strychnine poisoning. Recovered.

(7) Rat in 20 atm. O_2 for 5 minutes. Rapid decompression. Lay on its side partly paralyzed. Soon recovered and moved into cage. On pulling it out it struggled, and this caused a violent epileptic fit (due to displacement of gas bubbles by the struggling?). It quickly recovered and ran into the cage.

(8) Rat in 20 atm. O_2 for 9 minutes. Rapid decompression. Collapse paralysis, gasping respiration and death. Air bubbles everywhere in the right heart, liver, stomach and mesenteric vessels. General emphysema of the fat and connective tissues.

(9) Guinea pig in 10 atm. O_2 for 2 minutes. Rapid decompression. The animal at first appeared dazed but soon recovered.

(10) Guinea pig to 22 atm. O_2 in 4 minutes. Rapid decompression. Convulsions, rolling over to right, death. Froth in the heart and lungs. Some air bubbles in wall of intestine. Small pin point hemorrhages over base of brain. A few bubbles in the larger pial vessels.

The microscopical examination of the organs of these animals was carried out by Dr. Finlayson. In the central nervous system the gas bubbles formed small cystlike cavities surrounded by compressed and flattened nerve cells. The same kind of cavities formed in the liver. The bubbles set free in the vessels run together at less resistant points and the vessels become alternately occupied with columns of corpuscles and long bubbles of gas. Bubbles are also set free in all the connective tissue (lymph) spaces throughout the body and especially in adipose tissue. We have never seen bubbles actually within a muscle-fiber, nerve or other cell. The cells are not torn, but compressed and rendered anaemic. It is easy to conceive how the escape of gas bubbles into resistant structures, such as bone, aponeurosis nerve-roots and nerve-sheaths may give rise to the "bends" or pains so commonly suffered by caissoniers. V. Shroetter has published a figure exhibiting the air-bubbles in the coronary artery of a dog decompressed rapidly from 4 atm. He also gives a figure of the lesions produced in the spinal cord by the air-bubbles.

We have actually observed the production of air embolism in the vessels of the frog's web and bat's wing. The animals were exposed to 20 atm. for about 10 minutes. For about a minute after rapid decompression the circulation continued unaltered, then small dark bubbles were seen, first one, then another, and then numbers scurrying through the vessels, and driving the corpuscles before them. In a moment or two the vessels became entirely occupied with columns of air bubbles, and the circulation was at and end. By means of rapid recompression we have driven the gas again into solution, and have seen the corpuscles reappear in the capillaries and

the circulation become re-established. On very slowly decompressing the animals we have seen no gas bubbles appear.

Our large pressure chamber, pump and other facilities kindly provided by Messrs. Siebe and Gorman, the well-known marine engineers, has enabled us to thoroughly study the effects of rapid and slow decompression. The chamber was provided with a large tap, by means of which the pressure could be lowered from + 7 atm. to + O in about 10 seconds to 1 minute.

It was also provided with a pin point opening through which the period of decompression could be made to occupy 1, 2 or more hours.

Experiment 1. A large cat, two half-grown rabbits, two large rats and two white mice were placed in the chamber and the pressure raised to 105 pounds (+ 7 atm.). A ventilation current was maintained. All the animals appeared to be perfectly normal. At the end of an hour rapid decompression was brought about. The chamber filled with mist owing to the cooling of the expanded air. When the mist cleared we saw that the cat and one rabbit were dead, while the other rabbit was in violent tetanic convulsions.

On opening the chamber the rats were found to be dead.

The second rabbit died also and the mice alone survived.

There was emphysema of all the tissues and frothing of the blood in the right heart and lung. In the albino rats we could see extensive retinal hemorrhages.

(2.) A cat was placed in the chamber and the pressure raised to + 7 atm. in 50 minutes, and then rapidly lowered to + 0. The cat survived, for the tissue fluids had not become sufficiently saturated with air.

Our blood-gas analysis show that it requires an exposure of about 1 to 1½ hours at + 7 atm. to saturate the arterial blood with N_2 to the amount required by Dalton's law, and the tissue fluids must take far longer.

(3.) A large cat, a rabbit, two white rats and two mice were compressed to + 7 atm. in 50 minutes and kept at this pressure for 1 hour. Decompression occupied 1 hour. None of the animals showed any discomfort.

(4.) A Rhesus monkey, a rat and two mice were compressed to + 7 atm. for 4 hours. The animals seemed untroubled by the pressure. Decompression was started at 4.30 P. M. by opening the small tap; the last part of the decompression was hastened, and when, at 5.25, the pressure registered 10 pounds to the square inch, the large valve was opened and the pressure quickly brought to zero. On opening the chamber the monkey and the other animals seemed perfectly normal. On removing the monkey from the chamber he struggled to escape, but in the course of a minute or two suddenly became quiet and lay on his side gasping, with a peculiar cry. He gradually got more and more dyspnoeic, and his lips, tongue and face became markedly cyanotic. Despite energetic artificial respiration he died in about 10 minutes after removal from the chamber.

Post mortem. Heart: Not markedly distended, ventricles in "delirium cordis," auricles beating feebly. On opening the right heart a little deep purple frothy blood exuded, followed soon, however, by non-frothy blood. Mesenteric veins. Small air columns in several of these. Lungs perfectly healthy.

The other animals in this experiment did not show any decompression symptoms. The cause of the trouble was no doubt the acceleration of the last part of the decompression.

(5.) The experiment was repeated with another monkey (Rhesus). After being subjected to + 7 atm. air for 4 hours, 2½ hours were taken to decompress. There was not the slightest signs of decompression symptoms.

This experiment was repeated on this monkey three or four times a week for a month, the time for decompression being in each case 2 hours. There was never the slightest sign of decompression symptoms and the monkey remained in perfect health and maintained its weight. Toward the end of the period of compression it sometimes seemed to become sleepy. The body temperature remained normal.

The Treatment of the Decompression Symptoms.

As we have shown in the experiments on the frog and bat, the bubbles of air which develop in the capillaries can be seen to pass back into solution by a rapid reapplication of the pressure.

We have tried this in the case of larger animals.

Experiment 6. A large hutch rabbit was kept under a pressure of + 7 atm. of air for 4 hours and was then quickly decompressed. In a minute or so the rabbit developed typical decompression symp-

toms (*i. e.,* fell on side and limbs showed tetanic convulsions). The pressure was now quickly reapplied up to about + 5 atm. by emptying a large cylinder of compressed air into the chamber. The symptoms, however, remained unabated and the rabbit soon died. It was evident, therefore, that for the reapplication of pressure to be of any avail, the pressure must be very quickly re-established, and no time be given for the air bubbles to tear up and damage permanently the nervous tissues, nor to produce stasis of the circulation for too long a period.

We, therefore, repeated the experiment with the modification that the pressure was more quickly reapplied.

(7.) A cat and a hutch rabbit were subjected to an air pressure of + 7 atm. for 4 hours. Decompression was effected to zero in about 5 seconds, and as quickly as the taps could be opened (about 5 seconds) a large cylinder of compressed air was delivered into the chamber, thus raising the pressure to 95 lbs. in about 2 minutes.

At the moment of decompression the cat sprang to the window, excited and with widely dilated pupils. In a few seconds it became entirely paralyzed in the limbs, so that it fell helpless onto its side; its head meanwhile showed continuous side to side pendulum movements. There was no mystagmus. On recompression these symptoms gradually disappeared, the head movement being the first to go, then the pupils contracted to their normal size. Some 2 or 3 minutes after recompression to 95 pounds the cat tried to move about, but on each attempt fell helpless on its side. It soon gave up these attempts and lay in a semi-dazed condition. The pressure was maintained for 45 minutes and then slowly lowered. The cat recovered, and on removal seemed perfectly normal, and on being placed in his basket leapt over its side and escaped into the room. Next morning it was quite normal in every respect.

The rabbit was recomposed before it showed any symptoms of decompression and was quite normal on removal from the chamber.

All our other experiments on metabolism, oxygen poisoning, etc., show that for + 7 atm. (105 lbs.) 40 minutes is a safe period for decompression. The only cases in which it fails is when the animals have developed symptoms of oxygen poisoning and have become comatose, their body temperature lowered and lungs congested by too long a stay in the compressed air. The circulatory and respiratory organs then fail to rid the body of the gas with which it is saturated.

Our experiments confirm those of Bert.

The blood and tissue juices effervesce on rapid decompression like an opened bottle of soda water. The longer the shift the greater becomes the saturation of the body fluids, and the greater the risk of rapid decompression.

A 5 minutes exposure to + 20 atm. O_2 is sufficient to saturate rats and guinea pigs so far that they die on rapid decompression.

Animals can be exposed to + 7 atm. air with perfect safety for 4 hours and be brought out quite well when the period of decompression is made to last 2 hours.

Recompression, after rapid decompression, causes solution of the gas, and may, if quickly applied, save the life of the animal. Recompression has been found to alleviate the bends in most caisson works, and Mr. Moir introduced a boiler at the Hudson tunnel wherein recompression was applied with excellent results. At the Blackwall tunnel a "medical lock" was likewise employed, and the cases of bends frequently derived benefit from recompression followed by slow decompression. V. Schroetter, from his experience at Vienna caissons, considers recompression to be the sovereign remedy for caisson sickness if it can only be applied in time.

We will now contrast the experimental results with the periods of decompression employed at some of the chief caisson works, and then discuss the influence of age and habit of body on caisson illness.

Periods of Shift and Decompression at Caisson Works.

Atmosphere (max.)	Length of shift.	Period of decompression.	Place.
4½	4 hrs.	30 mins.	Chalonnes.
2	......	10 "	Lorient.
3½	4 hrs.	12 to 15 mins. (rule often broken by men)	Kehl.
3½	......	20 mins.	Trazegmies.
3	8 hrs.	4 to 5 "	St. Louis.
3½	4 "	10 "	"
4	3 "	18 "	"
2 to 3	8 "	4 " (often shortened to 30 secs. by men breaking the rules.)	Blackwall.

Triger recommended 7 minutes.

Barella recommended 10 minutes per atm.

Foley recommended 3 minutes, and considered slow decompression dangerous.

The Greek divers are usually pulled up rapidly.

Denayranzc for divers recommended 1 minute per meter.

Siebe and Gorman recommended deep divers to take 20 minutes in ascending.

Paul Bert recommended short shifts and 30 minutes decompression for 2 to 3 atm. and 60 minutes decompression for 3 to 4 atm. The decompression chamber must, he says, be warmed.

For deep divers he recommends a halfway resting stage.

Influence of Age.—Pol and Watelle state that young men of 18 to 26 years stand the work best; out of 25 men discharged on account of symptoms 19 were over 40 years old.

E. H. Snell found that at the Blackwall tunnel men below 20 were immune to accidents of decompression. This agrees with the general tenor of experiments on animals. The young bear rapid decompression best. He publishes the following table:

Age.	No. of men passed.	No. of cases taken ill whose ages are recorded.	Illness.
15 to 20......	55	0	0.0%
20 " 25	145	15	10.3%
25 " 30......	152	37	24.3%
30 " 35......	91	19	20.9%
35 " 40	61	14	22.9%
41 " 45	38	10	26.3%
45 " 50......	8	5	106.0%

Habit of Body.—In stout men or men of heavy build the liability to illness is greatly increased. A. Smith compiled the following table from the records, at Brooklyn Bridge, of men under 45 years:

	Spare.	Medium.	Heavy.
Lost little or no time from sickness	25	14	3
Taken sick..	28	22	86
Paralyzed...............	2	3	8
Died................	..	..	3

Considering that under 45 years heavy men are greatly in the minority, this report is most striking. Snell excluded old and heavy men from the Blackwell tunnel caissons and lost no cases. Men prematurely gray and with commencing arterial degeneration should also be excluded.

There is no clear proof that long continuance at the work renders a man immune. Cases frequently occur among old hands. The men among the new hands who are liable to attack are discharged.

Exertion.—A. Smith says that severe exertion after decompression predisposes to attack. This is to be expected, for the exertion may force the air bubbles in the blood vessels out of harmless into harmful places. We have brought on attacks of convulsions by massaging the abdomen of rapidly decompressed animals. The monkey in Experiment 4 died after struggling.

Ventilation.—E. H. Snell lays great stress on the good results which follow free ventilation of caissons. He says: "An increase of CO_2 from .04 per cent. to .1 per cent. at 30 pounds pressure is the forerunner of much illness."

In one of the Blackwall caissons where the pressure was 25 to 35 pounds illnesses were occurring at the rate of 7 a day. The men were working at the bottom of the caisson; the air supply pipe opened near the roof and the air escaped again through the roof. The supply pipe being lengthened, the illnesses at once dropped to an average of 1 in 2 days.

The following table has been compiled by Snell to illustrate the effect of increased ventilation:

Caisson I. Pressure + 25 to 35 lbs.

Cu. ft. of air per man per hr.	No. of days.	Cases of illness.	Illnesses per 100 days.
Below 4,000......	13	41	315.5
4,000 to 8,000	26	78	300.0
8,000 to 12,000....	10	8	80.0
Above 12,000. ...	12	4*	33.3

In other tables Snell seeks to prove that a ventilation of over 12,000 cubic feet per man abolishes illness. He points out that candles smoke in compressed air, but cease to do so if put within a lamp chimney, so as to increase the draft. As the velocity of diffusion of a gas varies inversely as the square root of the density he attributes the smokiness of the candle to the slow diffusion of the products of combustion.

Snell suggests that an increase of CO_2 from .04 to .1 per cent. may actually be the cause of caisson illness and that CO_2 may be the gas which in particular is set free in the blood decompression. There is no evidence that this amount has the slightest toxic effect.

* Only 2 or 3 men were in the caisson on the days when these illnesses occurred, and so the total volume of air supplied to the caisson was reduced, i. e., the air supplied per man was high, but low per caisson.

At Brooklyn caisson with .33 per cent. CO_2 was found on analysis, which at 3 atm. gives .99 per cent. atm. CO_2. At Blackwall with .1 per cent. CO_2 and at Brooklyn with .33 per cent. CO_2 the extra CO_2 would cause a slightly increased depth of breathing and thus practically no effect on the composition of the alveolar air in contact with the blood. This, at least, would seem to follow from experiments recently communicated to the Physiological Society by Haldane and Priestley.

We cannot suppose that a small percentage of CO_2 In the air would contribute in any way to the setting free of CO_2 bubbles on decompression. It is true that Paul Bert found 15 per cent. CO_2 and 85 per cent. N in the air obtained from the heart of animals killed by rapid decompression. When blood is exposed to air it gives off CO_2 owing to the very low partial pressure of this gas in the atmosphere. Similarly when nitrogen gas is set free in the heart, some CO_2 will diffuse out and Bert found some traces of oxygen. Bert's analyses of blood gases show that the CO_2 in the arterial blood is, if anything, lessened under the influence of compressed air, and our results confirm Bert.

Hunter notes that the most dangerous times in the Forth Bridge caisson were (1) when soft wet silt was being removed, (2) when concreting was going on. It must be borne in mind that the presence of traces of a toxic gas such as H_2S is dangerous in compressed air, owing to the increase in the partial pressure of such impurities. In the case of CO the increase in partial pressure will be balanced by that of oxygen. But the CO might produce its effect on decompression. The caissons become fouled with the excretions of the workmen, and it is very needful that proper earth-pails should be provided.

As matters stand at present it is not easy to explain Snell's ventilation results, and it is urgently required that they should be confirmed.

Increased rate of ventilation has not seemed to affect our animals in regard to CO_2 output.

Selection of Workers.—From the records of caisson sickness and from our experimental results we conclude that the men selected for high pressure work should be small men, of spare and wiry habit, not older than twenty to twenty-five. The men should be total abstainers and abstemious in all their habits.

The men should all be tested at low pressure first, and those who suffer from symptoms should be discharged.

Rules for Caisson Work.—The following we consider to be safe rules for working:

The longer the shift, the greater is the saturation of the body fluids with gas, and the slower therefore should be the decompression.

The higher the pressure, the shorter should be the shift, and the longer the decompression.

We suggest the following times as safe:

Atmosphere.	Pounds.	Shift.	Decompression period.
+ 2	30	4 hrs.	30 mins. to 1 hr.
+ 3 to 4	45 to 60	4 hrs.	1 to 2 hrs.
+ 5	75	1 hr.	1 to 2 hrs.
+ 6 to 7	90 to 105	30 mins. to 1 hr.	2 hrs.

To prevent men breaking the rules the decompression chamber should be provided with one cock only, which will allow decompression to take place in the given time. A separate lock should be provided for the rapid passage of material. The decompression chamber must be artificially warmed, so that the temperature does not fall below 60 degrees F., and it must be thoroughly ventilated during decompression.

The ventilation of the caisson or diving apparatus should be very free, and the temperature of the air should be about 60 degrees F. The men should remain quiet for an hour or so after decompression and be recompressed on any sign of sickness. Paul Bert recommends that oxygen be supplied to the decompression chamber in order to hasten the diffusion of nitrogen. This is no doubt a means by which the period of decompression might be shortened, but it introduces the danger of oxygen poisoning.

We are of opinion that by proper choice of men and regulation of the shift and decompression period, work could be carried out without loss of life at a depth of even 200 feet, *i. e.*, about 7 atm., or + 100 pounds pressure.

Summary.

(1) Compressed air at and above 4 to 5 atm. lessens the CO_2 output, and lowers the body temperature.

(2) Oxygen at and above 1 atm. has the same effect. It is a sign of oxygen poisoning.

(3) Compressed air at 10 atm. is more damaging, at least to small animals, than oxygen at 2 atm.

(4) Compressed air increases the loss of body heat both because it is a better conductor and because it is saturated with moisture.

(5) The saturation of the air with moisture does not prevent evaporation from the body because the skin temperature is above that of the air. The wet air by damping fur or clothes causes loss of heat.

(6) Highly compressed air may possibly interfere with the diffusion of CO_2 from the alveolar air, and may, owing to increased friction, hinder the passage of air in and out of the air-tubes.

(7) The nitrogen output is not altered in any noteworthy degree by exposure for six hours to 8 atm. air.

(8) Inflammation and consolidation of the lungs is produced by exposure to 8 atm. air for about 24 hours. One and one-half atm. of pure oxygen has a similar effect. The higher the oxygen tension the more rapidly does the inflammation ensue, *e. g.*, 6 atm. O_2 produces marked congestion in 2 hours.

(9) It does not seem likely that inflammation of the lungs should be produced in the pressures and times of exposure usual in caissons.

(10) Excised frogs' hearts, muscles and nerves are not rapidly poisoned by even 50 atm. O_2. A heart will beat more than an hour exposed to this pressure. The vagus nerve endings appear to be paralyzed by such exposure, while inhibition can be obtained by stimulating the crescent. The thin sartorious muscle is much more easily affected than the gastrocnemius, and soon gives a curve like a fatigue curve.

(11) All animals investigated, vertebrates and invertebrates, are instantly convulsed and killed by exposure to 50 atm. O_2.

(12) Convulsions are frequently produced in vertebrates by exposure to 4 to 5 atm. O_2 while exposure to 6 to 25 atm. O_2 produces dyspnoea and coma, and the convulsive stage does not usually appear. Cleaning movements, salivation, gaping, jerky deep respiration, are symptoms which precede the convulsions, and coma soon follows them.

(13) We have not observed convulsions with air pressures up to 12 atm. Salivation, dyspnoea, and coma are the symptoms.

(14) The blood-gases increase in compressed air or oxygen according to Dalton's law, but the process of complete saturation of blood and tissues takes some time.

(15) The circulation is unaffected mechanically by compressed air.

(16) The cause of caisson sickness is the escape of gas bubbles in the blood vessels and tissue fluids on decompression. An animal exposed for 4 hours to 8 atm. air and quickly decompressed is like an opened bottle of soda-water. The fluids of the body generally effervesce.

(17) The effervescence can be studied in the circulation of the frog's web or bat's wing, the animals being inclosed in a suitable chamber. It takes a little time for the bubbles to grow to an appreciable size.

(18) Recompression causes the bubbles to go into solution, and if applied quickly enough the circulation recommences.

(19) The bubbles after rapid decompression can be seen post-mortem in the blood vessels, in the heart, retinae, aqueous humor, connective tissue spaces, etc. The alimentary canal is blown out with gas. The bubbles produce cyst-like cavities in solid organs, *e. g.* in the central nervous system, the liver. The cells are compressed round these cysts.

(20) In the case of oxygen an animal may recover after an extraordinary amount of this gas has been set free by rapid decompression. The nerve cells are not killed by the oxygen bubbles, and the animals are convulsed and exhibit hyper-reflex-excitability.

(21) The varying symptoms of caisson sickness are due to the varying seat of the air emboli.

(22) Young men escape caisson sickness owing to the elasticity of their tissues, and greater facility for collateral pathways of circulation.

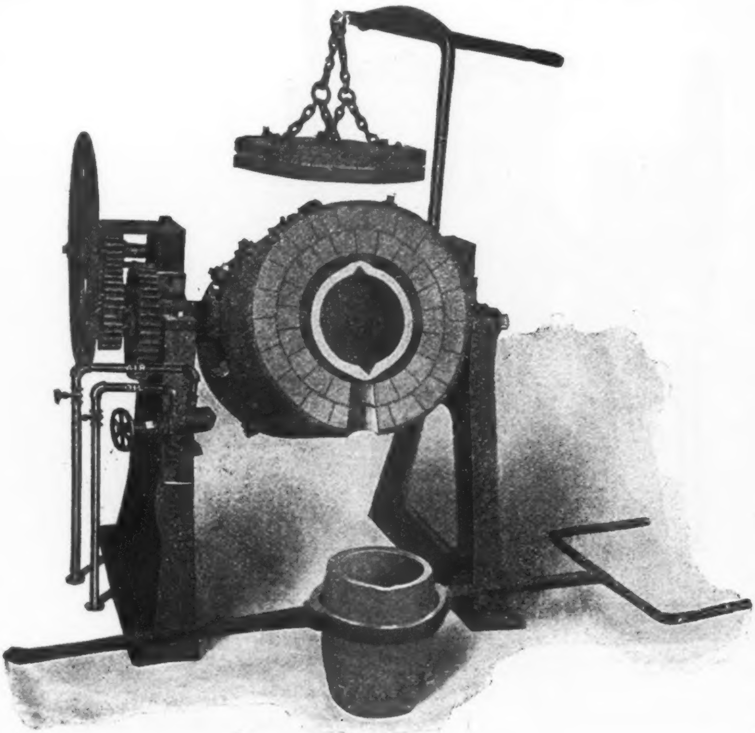
(23) Animals can be safely exposed to 8 atm. of air for four hours if two hours be spent in gradual decompression. Such exposure can be safely repeated three times a week.

(24) By the choice of suitable men, and proper regulation of the period of compression and decompression, caisson and diver's sickness can be avoided.

Melting Metal with Oil and Compressed Air.

A metal melting furnace, using fuel oil and compressed air to attain the desired temperature, was invented and patented by David R. Steele, of Curtis Bay, Md. It is now placed on the market under the name of the Steel-Harvey metal melting and refining furnace by the Monarch Engineering and Manufacturing Company, of Baltimore, Md.

controlled by the operator. The burner is designed somewhat like an atomizer. It is claimed that it differs from other burners which produce a spray effect and form large globules of oil that drop and are not consumed. All the oil used in this burner is said to be consumed. The burners take from 10 to 15 cubic feet of free air per minute and to operate with air under from 40 to 60 pounds pressure. The makers declare that the higher air



THE STEEL-HARVEY MELTING FURNACE.

This furnace consists of an outer steel shell and an inner one of fire brick. The crucible rests on the bottom on a square graphite block with an air space between it and the fire brick lining. The flame is played directly on this graphite block and circulates entirely around the crucible.

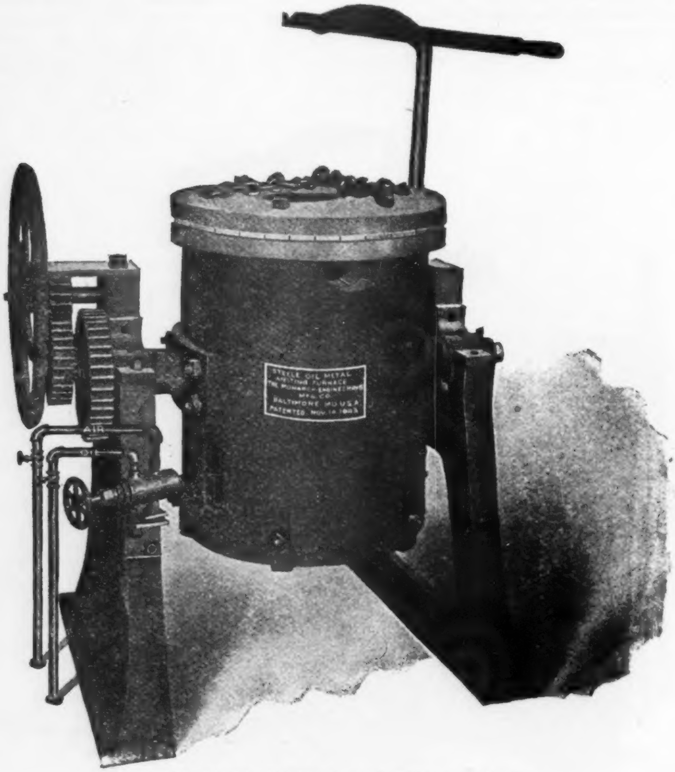
The furnace is swung between two upright trunnions and is tilted by gears

pressure will give greater economy of oil. The air is controlled by the main piston valve which operates a needle point at the extreme oil outlet.

For the smaller sized furnaces it is said that 20 heats a day may be made covering 2,400 pounds of metal. The largest furnaces are built for from 3 to 5 heats per day and 4,000 pounds of metal.

In starting the burner a lighted torch is used, the air and oil being turned on slowly until the oil is thoroughly ignited.

The accompanying illustrations will give an idea of the general construction of the furnace.



THE STEEL-HARVEY MELTING FURNACE.

gant in the use of steam. Aside from being extravagant in the use of steam, this type gives considerable trouble in the reverse valve rod, plate and bolts.

In my experience with the single and duplex flywheel type I have observed a common fault—that of insufficient discharge valve area. With such faulty construction trouble results when the demand for air approximates the capacity of the compressor.

Builders of compressors in quoting capacities base same on cubical contents of cylinders, when experience has shown that under most favorable conditions not over 92 to 97 per cent. of the cylinder capacity can be discharged at any one stroke. In some cases the area of the opening in the valve cage is less than the valve area. Diagram 1 was taken from a

Air Compressors.*

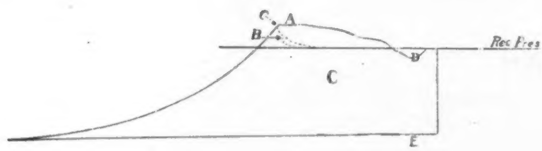
As compressed air installations multiply and are now found in conjunction with nearly all steam plants of even moderate size, it behooves engineers to devote some thought to the proper design, construction and operation of air compressors.

The type commonly known as the locomotive style is the most durable and applicable per unit of output, but is extrava-

* Paper by W. F. Stack in *The National Engineer*. Illustrations given through the courtesy of *The National Engineer*.

compressor with this form of construction, showing pressure at *A* to be ten pounds higher than that in the receiver. The compression point should extend as high as *C*, or very near it; then at the instant the valves opened should follow the discharge line *B* to the end of the stroke.

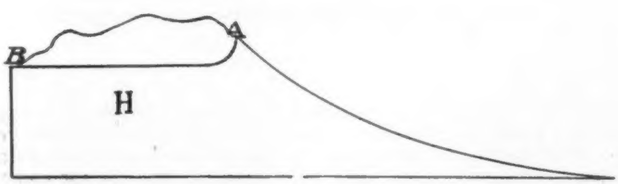
Fig. 1



D shows a leak which was credited to the piston packing, as the leak disappeared after new rings were put in. Vibrations shown at *E* indicates weak springs chattering on seats.

In a compressor of ample discharge valve area the discharge line would be as

Fig. 2.



in Figure 2 (*A* to *B*), the same as obtains in the best makes of ammonia compressors. If air cost one-tenth as much as ammonia more attention would probably be paid to the details of its economical compression.

The inlet pipe should be so placed as to provide air as cool and dry as possible. In some cases the inlet pipe is extended to the top of the building in which compressor is located, and the top of pipe covered with a fine screen to prevent the entrance of injurious matter with the air.

In the December (1903) number of *The National Engineer,* on page 17, appeared an article, "Explosion of Air Receiver." In reference to some of the statements contained in that article I would say that a 14 by 14 by 18 inch air compressor, with 100 pounds steam pressure, will pump and maintain 20 to 25 per cent. more air pressure than the steam pressure stated—or 120 pounds of air pressure could have been maintained under the conditions as described. *Proviso,* that the compressor was of the flywheel type.

Now with reference to the compressor with the poppet discharge and mechanically opened inlet valves, in this type of compressor there is generally found a re-expansion line like *A*, Figure 3. This effect results from opening the valve when the pressure in the cylinder is at receiver pressure, whereas with the spring inlet valves, the air contained in the clearance space must expand, and not until the pressure in the cylinder reaches a point somewhat below the atmospheric pressure, will the valves open, as shown in Figure 4, the discharge valves were leaking very badly, anyway. The card will plainly show the action of the air; the point I wish to make clear is shown from *A* to *B*.

Compressors of the mechanically opened inlet valves are subject to a very disagreeable noise, the instant the valves begin to open, caused from the air contained in the clearance space exhausting into the atmosphere. This noise may be reduced somewhat by making the eccentric a little late, allowing air entrapped in clearance space to expand down to atmospheric line before the valve begins to open, but in doing this care should be taken that the valve is not too late in closing, thereby lowering the efficiency of the cylinder.

Therefore a card with a re-expansion line, shown in Figure 3, would be a misleading one; and calculating the efficiency from the card would show, say, an apparent efficiency of 90 per cent., while the actual efficiency would be about 80 per cent. where the re-expansion, or the air contained in the clearance space were allowed to expand down to atmospheric pressure before the valve began to open.

To determine where the valve should open from the card, Figure 3, you will first have to ascertain the percentage of clearance, then erect the theoretical curve, according to the law of expansion of gases, where the theoretical curve intersects the atmospheric line. This is the point where the valve should begin to open. It is obvious that as long as there is pressure (above atmosphere) in the cylinder, it is useless to open the inlet valve.

Figure 5 represents an ideal steam card for a Corliss straight line air compressor with but one exception, according to the books, but is very satisfactory under the circumstances—the exhaust valves are late in opening. The engine from which the card was taken is from the wrist plate single eccentric type, and would not permit of any better action. In reference to compression, this is one case where I side with Non-Compression Johnson. I have been unable to see where an engine of this type has any use for compression. In this case there is from 30 to 40 pounds compression in the air cylinder, until the piston reaches end of stroke. The air contained in the clearance space has certainly got to expand, and before this operation ceases, the initial pressure in the steam cylinder is up to its highest point, and the piston is on its return stroke, and I must

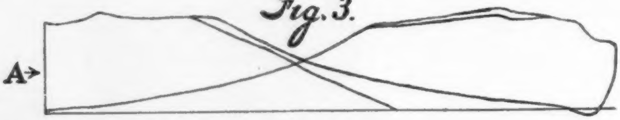


Fig. 3.

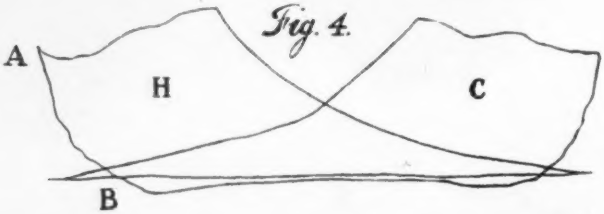


Fig. 4.

say we are not troubled with hot bearings, and the engine runs as smoothly as a good many engines that have compression. I am not of the opinion that all engines will run quietly without compression, whether or not an engine should have compression depends upon circumstances.

We are confronted now and then with a problem. Here is one some of the readers of *The National Engineer* can solve for themselves, see Figures 6 and 7. One firm manufacturing air receivers claim that No. 5 is proper for the air entering at the top, the cooler air going to the bottom, thereby insuring better service from the many devices operated by compressed air. Still another firm says No. 7 is the proper way to make connections and that the temperature is practically the same, bottom and top, that the air in rising tends to rid itself of contained moisture. They also recommend carrying water in the receiver, the surface of which should be just above the end of the pipe, thereby forcing air through the water, separating all the dirt and oil, etc.

I am of the opinion that No. 7 is the proper one, and that if water was allowed to collect in No. 6, which it most assuredly will, the machines, whether engines, pumps, hammers, etc., in operation are liable to a good dose of water, which is liable to do harm in many instances.

Fig. 6.

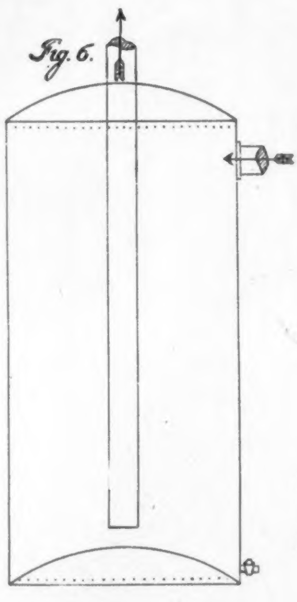
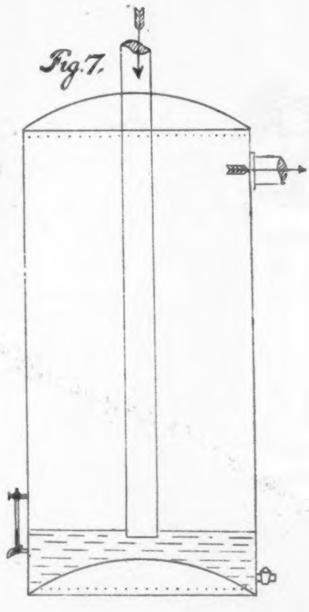


Fig. 7.



Air Brake Hose Testing Apparatus—N. & W. Ry.

In view of the expense to which the Norfolk & Western Railway has been placed in supplying air brake hose, devices for thoroughly testing this material have been designed by the motive power department, and it is found by careful testing that the efficiency of the material may be thoroughly determined before being placed in service. The illustration which we present herewith show the device for the bursting test to the right of Fig. 1, and the apparatus for the buckling test to the left of the same figure. Another view of the buckling test machine is shown by Fig. 2. The latter machine is devised to reproduce, as far as possible, the vibration or buckling to which hose is subjected

on the road. It is operated by a pulley driven by a belt from a counter shaft above. On the shaft of this pulley is a crank for giving motion to a vibrating arm. The illustrations show very clearly the manner in which the hose is attached at one end to a point on the table connected with the air supply pipe, and on the other ned to a vibrating arm. In order to save time in placing and removing the hose, unions are so arranged that the hose may be held securely by a lever clamp. A

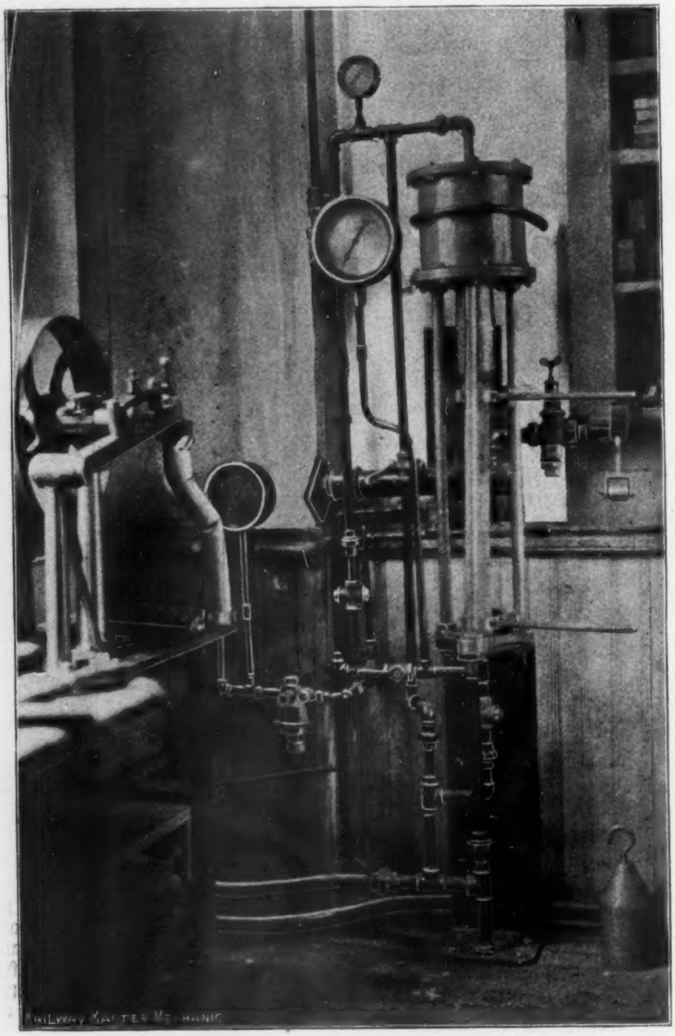


FIG. I.—HOSE TESTING APPARATUS—N. & W. RY.

constant pressure of air is maintained in the hose by using a standard Westinghouse signal line reducing valve, and it is found that the best results are obtained by fifteen pounds pressure. In the union between the reducing valve and the hose is a copper diaphragm in which is located a small hole of about one one-hundredth of an inch in diameter. This is provided to reduce the flow of air into the hose so that when the hose is sufficiently worn by the buckling action to allow the escape of air it cannot be supplied fast enough to maintain pressure therein. In order to announce a break and consequent leak in the hose, a whistle is attached to the end of the vibrating arm, as shown in the illustrations, and connected to the upper end of the hose. Air is maintained in the hose and kept from leaking through to the whistle by a plain bevel seat valve, which is held closed by pressure of the air. On the opposite side is a spring to unseat the valve, which is set at 12 pounds. When a leak occurs in the hose and the pressure is reduced below 12 pounds, the valve unseats, permitting air to pass to the whistle, announcing the leak. An ordinary cyclometer is arranged on the frame supporting the machine and is operated by the crank engaging the lugs thereon, so that the number of vibrations are counted automatically. The hose is usually given about 120 vibrations per minute,

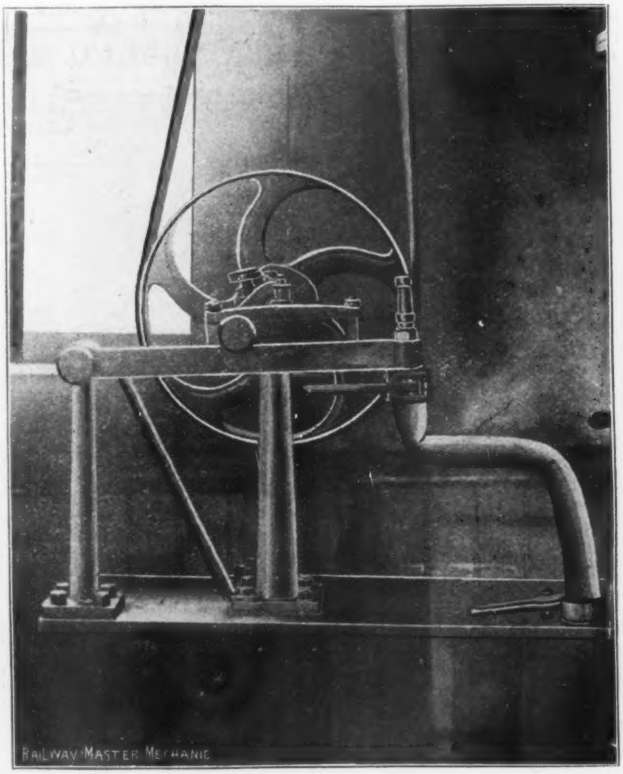


FIG. 2.—HOSE TESTING APPARATUS—N. & W. RY.

and while no specifications have been prepared in this direction, the hose should stand about 75,000 vibrations, or bucklings, before failing.

The apparatus for the bursting test consists of a frame for supporting the hose and pipe connections and a differential piston for supplying the necessary pressure. The position of the hose is shown in the illustration and the manner in which it is clamped is also indicated. In making the test water is admitted from below to fill the hose and small cylinder. The valve is then closed and air admitted to the top of the upper and larger cylinder, forcing the piston down and supplying a pressure to the hose. The diameter of the smaller piston in this instance is 2¾ inches, and the larger, or air cylinder, is 8 inches in diameter. The Master Car Builders' Association requires that a test hose must stand for ten minutes a pressure of 500 pounds before bursting.

Besides the appliances here described the road has simple tests for friction and stretching, as required by the M. C. B. Association. In presenting these illustrations and description we acknowledge the courtesy of Mr. W. H. Lewis, superintendent of motive power of the Norfolk and Western Railway, and Mr. W. W. Lemen, engineer of tests.—*Railway Master Mechanic.*

A Compressed Air Installation.*

Much is being said and written along scientific as well as practical lines of the various phases of mining installations. Of these, the question of power is receiving its share of attention, as between water, electricity, compressed air or steam. Water is used largely as the prime mover in the production of both electricity

FIG. I.—NORTH STAR M. CO. COMPRESSED AIR POWER PLANT, GRASS VALLEY, CAL.

*Written for the *Mining and Scientific Press* by Walter W. Bradley.

and compressed air. The one advantage of electricity which stands out above all others is its susceptibility to long-distance transmission—present installations reaching up to 300 miles. It may be used direct-connected or belted, or it may be used to compress air, which in turn is used direct. In the latter case, however, at many mines it might be cheaper to compress the air directly with the water power, without electricity as an intermediate stage. Compressed air is of manifest value around a mine, and especially underground, where, after it has done its work as an agent for power, the exhaust serves to aid ventilation. Electricity, too, is being applied to the operation of rock drills. Compressed air is used in pumps, hoists and other engines in lieu of, and as interchangeable with, steam, as will be observed below.

An important installation in the way of compressed air power plants is illustrated herewith in Figure 1, being that of the North Star mine, near Grass Valley, Nevada County, Cal. At the time the photograph was taken the plant had a capacity for producing 500 H. P., but this has since been increased to 800 H. P. One of the compressors therein is driven by a tangential water wheel, 30 feet in diameter, using a single jet under pressure of 775 feet head. A speed of 65 revolutions per minute is maintained and the compressor has automatically operated governors, which (set at 90 pounds pressure per square inch) cut out (blow off) the excess of air not being used, down to 15 per cent. of the volumetric capacity of the cylinders. This 30-foot water wheel was designed to withstand up to 200 revolutions a minute (a peripheral speed of about 20,000 feet per minute). The first wheel put in was of 18½ feet diameter, to run at 110 revolutions per minute, under 750-foot head, developing 300 H. P. The compressor is direct-connected to the 30-foot wheel, and is of four single-acting cylinders—one low and one high pressure on each side—hav-

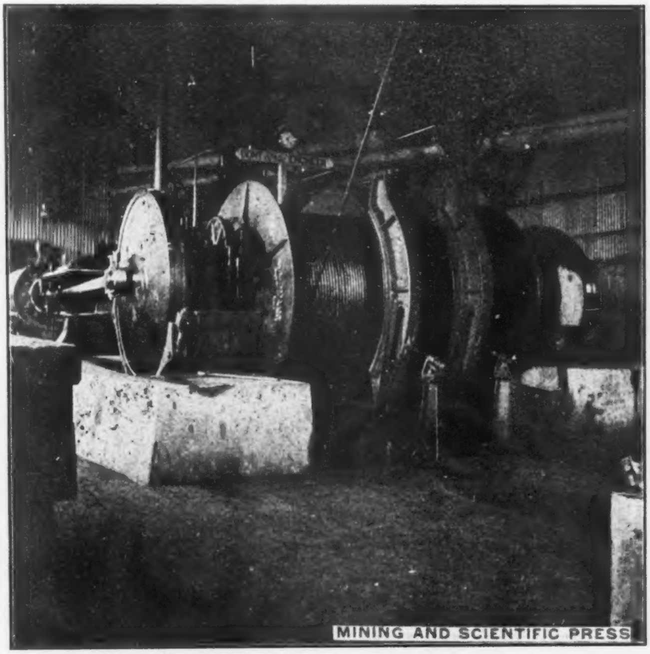


FIG. 2.—HOIST AT CENTRAL SHAFT, NORTH STAR M. CO., GRASS VALLEY, CAL.

ing a common stroke of 30 inches. The low pressure cylinders are 30 inches in diameter and compress the air to 25 pounds per square inch. The high pressure cylinders are 18½ inches in diameter and raise the pressure to 90 pounds per square inch. Between the high and low pressure cylinders the air passes through a series of cooling pipes set in the waterway of the wheel pit.

The compressed air is conveyed by pipe lines to the several workings of the company, the principal one of which is the Central shaft and its connections. The hoist used there is shown in Figure 2. It is of double-drum, direct-connected, with both post and band brakes, and has a capacity for raising 2,400 tons per day from 1,625 feet depth. Allowing 2 minutes for a round trip, hoisting in balance, with 3 tons of rock per skip, this would require 13 1-3 hours, leaving 10 2-3 hours for handling tools, timber and men and hoisting water. The compressed air before use in the engines of the hoist is reheated by crude oil in a furnace placed in a separate room to the rear of the engineer.

The Central shaft at a depth of 600 feet cut the New York Hill vein, and at a depth of 1,625 feet the main North Star fissure was struck, being about 4,000 feet on the dip of the vein. A 50-foot sump was sunk and stations cut for ore bins and pumps. From there a raise of 1,600 feet was driven in the vein most of the way, and cutting the bottom of the old workings. That the ore values are well maintained throughout this entire depth is shown in the annual report of President Hague of the North Star Co. (see *Mining and Scientific Press*, March 26, 1904, p. 217). Of the values, 90 per cent. is in free gold, and the ore carries 3 per cent. auriferous sulphides, principally pyrite, but with some galena. The Central shaft is sunk in grano-diorite and in diabase, the contact crossing the shaft irregularly and sometimes following down the centre line. However, the two formations were found so tightly "frozen" that the contact never showed any "let go."

Two triple expansion, duplex pumps in the station at the bottom of the shaft raise from 500 to 700 gallons of water per minute a height of 1,400 vertical feet in a single lift. These pumps use air at 90 pounds pressure, reheated by crude oil at the pumps. For the rainy period in the spring it is necessary, in addition to the pumps, to use a 3-ton bailing tank. Ventilation in the workings passes down the incline and up the vertical shaft, partly due to the collar of the Central shaft being 50 feet higher and partly because the gases from the oil combustion in the air heaters are discharged up into the vertical shaft. The draught is so strong as to blow out a lighted candle. To provide milling facilities for the increased ore reserves opened up by these developments, the 40-stamp mill at the North Star (incline) shaft is being remodeled and a new 40-stamp mill is being built at the Central shaft.

Making an Air Compressor.*

The advantage of the use of compressed air, its adaptability, cleanliness, safety, and the ease with which it can be manipulated, are so well known that those who are the fortunate possessors of an installation are surprised that they managed for so many years without it; and those who are debarred from its adoption, either by the initial expenditure or kindred objections, look forward to the time when they will be enjoying the same advantages as their more opulent or fortunate contemporaries.

The time has gone by for considering the *advisability* of adopting this form of energy. Having passed the experimental stage, the question is now, not "*shall* we have it?" but "*how* shall we obtain it?" also "which is the best form of plant and tools?" Of the latter little need be said; tools are being supplied in this country that are beyond praise, and from the commencement of this industry, greater success appears to have attended the manufacture of tools than of compressors, particularly in the case of those driven by belts.

My experience of the earlier forms of compressors has not been encouraging. History appears to have repeated itself in perpetuating the same errors—now remedied—that dogged the steps of the earlier machine makers, in listing the compressors beyond their average capacity of delivery, combined with insufficient driving power and unreliability of the working parts, notably the valve gear. Experience has now evolved compressors that will run continu-

* Written by "Works Manager" for the *Engineering Review* (Eng.).

ously for any length of time without attention, and can be depended upon to keep up the finger of the pressure gauge. This result has not been achieved without cost, which has no doubt influenced the price-list; and small or struggling works, whose finances are not in a robust condition, but who find the comparatively cheap drills, hammers, etc., within their reach, are sometimes compelled to forego the advantages of the system on account of the initial cost of a good compressor plant. Such has been the writer's experience, and possibly that of many others, the difficulty in the present case being surmounted by constructing a compressor out of such odds and ends and spare engine parts as are usually to be found in a general shop; and as it proved satisfactory, I venture to give it for what it is worth.

We had originally a small compressor that was quite inadequate, and the ratchet-brace was often brought into action because the compressor would not supply sufficient air to keep the tools working continuously. A constant supply of air at full pressure was necessary to make its use popular. We had, fortunately, the working parts of a broken-up locomotive—the slide-bars, crossheads, connecting-rods and crank, and inside cylinders 12 inches diameter by 18 inches stroke. The cylinders were larger than required, and were therefore bushed to 8 inches diameter, as shown in the diagram, a flange being cast on one end of the bush and a loose ring-flange fitted to the other end; both flanges a driving fit in the bell-mouth of the cylinders, the covers making the joint both for air-pressure and water-jacket. This bush also gave an ample water-jacket around the cylinder walls, the water flowing through the ports and out at the top of the steam chest. The same result might be obtained from a pair of ordinary flanged pipes. Pedestals were made to carry the crank, and the rods and slide-bars were coupled in the usual manner and fixed on a cast-iron inverted trough section-bed. From the fly-wheel of a shearing machine a wheel was cast which also acted as a fast-driving pulley; a loose pulley of light construction was also made ¼ inch less in diameter. The jacket water was taken from the works main by two ⅜ inch diameter pipes, and entered the cylinder jackets at the bottom at a temperature of 48 degrees, leaving at the top of the steam chest at a temperature of 80 degrees. The receiver—an old boiler barrel—was placed horizontally above (for want of space) on two wrought-iron legs, and was fitted with a lever safety valve. The cylinders were made single-acting by leaving the back cylinder cover open to the atmosphere, and fixing inlet and outlet valves on each of the front covers, provision being made to fix a valve-box on to the back cover, should it be found necessary to provide a greater volume of air than could be obtained from the single action. It was also arranged that one cylinder could be thrown out of operation, should the supply be beyond the requirements, by introducing a two-way cock in the delivery pipe of one of the cylinders, by means of which air could either be passed into the receiver or allowed to escape into the atmosphere. The piston was simply a solid block fitted with three bronze rings ⅜ inch wide and ¼ inch thick; the piston was lengthened to fill up the clearance spaces at the ends of the cylinder, only $\frac{1}{16}$ inch being allowed between the piston and cylinder cover at the end of the stroke. The inlet and outlet valves were of the simplest kind—ordinary poppet valves with gun-metal seats. It is possible that more efficient valves might be constructed, but none that would give less trouble. The air is drawn into the cylinder through the lower valve, whose lift is regulated by the lower end of the upper valve, through which the air is delivered into the pipe leading to the receiver. The fast pulley, or fly-wheel, is driven by a 7-inch belt, and revolves at a speed of 64 revolutions per minute, the belt being moved on the pulleys by means of an ordinary striking-gear.

This compressor has been working for 20 months without requiring one hour's repair; occasional lubrication is all that has been necessary. The starting-gear is under the control of an adjacent machinist, who regulates the running of the compressor in accordance with the pressure-gauge reading. The leading dimensions are as follows: Length of receiver, 10 feet 4 inches; diameter, 3 feet 10 inches; diameter of cylinder, 8 inches; stroke, 18 inches; diameter of fly-wheel, 4 feet 3 inches; diameter of inlet valves, 1¾ inches; diameter of delivery, 2 inches; width of belt, 7 inches; temperature of jacket-water, inlet, 48 degrees; outlet, 80 degrees; capacity, 80 cubic feet of free air per minute compressed to a pressure of 80 pounds per square inch.

Pneumatic Molding Machine.

A molding machine differing in some respects from any on the market is manufactured by Charles Herman & Son, of Allegheny, Pa. The machine was invented by Charles Herman. While there are many methods in use on power molding machines for the purpose of settling sand about the pattern, this machine is the one on which a jarring method is utilized and may be operated either by compressed air or steam. Molds with patterns from 1 to 12 inches in height can be rammed in from 10 to 15 seconds without the aid of hand ramming. In the larger sizes the machine handles molds of a weight, including the patterns, up to 1,200 pounds.

Four views of the machine are shown in the illustrations. Figure 1 is a front view of the machine, with molding board and pattern in place. Figure 2 is a similar view to Figure 1, but showing the pattern plate in a vertical position. Figure 3 is an end or side view of the machine, and Figure 4 shows the jarring mechanism. The stripping plate is not seen in any of the illustrations.

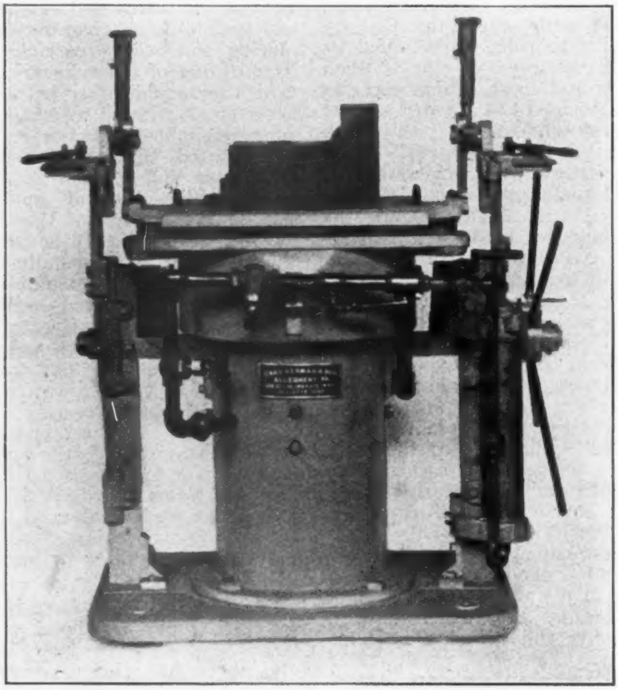


FIG. I.—FRONT VIEW OF MOLDING MACHINE WITH MOLDING BOARD AND PATTERN IN PLACE.

The machine is supported on a base plate, upon which there is a jarring block. There is a cylindrical casing extending up from the base plate around the jarring block which is secured to the base plate by bolts. A cover with a flange to protect the enclosed mechanism fits over the upper end of the casing. The pattern plate has lugs or pins supporting the

stripping plate and guiding the flask into place. The jarring mechanism is within the cylindrical casing and is separately shown in Figure 4. This consists of a central post, secured at the upper end to a crosshead sliding on guides inside the cylindrical casing and carrying the plate supporting the mold together with the flanged casting which covers the cylin-

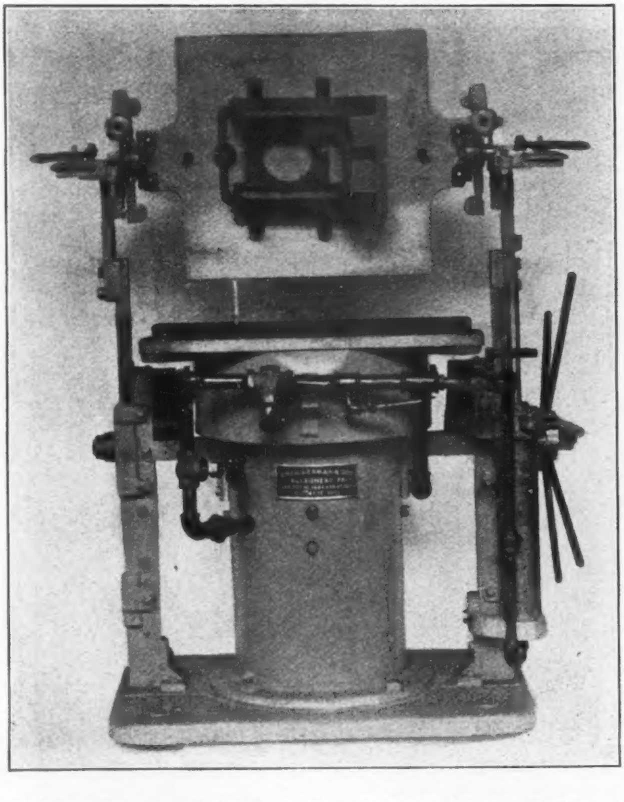


FIG. 2.—FRONT VIEW OF MACHINE WITH PATTERN PLATE IN VERTICAL POSITION.

drical casing. When in the lowest position the lower end comes in contact with the jarring block in the centre of the base plate. Fitting around the post or shaft is a stationary cylinder attached to the cylindrical casing extending up from the base plate. This cylinder has a valve chest containing a slide valve, which controls the admission and exhaust of the air or steam. A piston is permanently attached to the post and causes the post to ascend or descend as the air is admitted to the cylinder above or below the piston. The slide valve has a stem extending through a packing box on the upper end of the valve chest and has nuts at the upper end for the forked end of a rocking lever. This lever is pivoted to a standard screw on the upper cylinder head. The opposite end of the lever is also forked and fits around a rod coming down from the crosshead.

The piston and crosshead are raised by admitting air below the piston, the pattern plate, stripping plate and flask traveling with the piston and post. As the crosshead rises, the rod connected with the

rocking lever throws the valve in such a way as to cause the air in the lower end of the cylinder to exhaust, while the working fluid at full pressure is admitted above the piston. This causes the post to descend rapidly and strike the jarring block. The machine is set to strike about 120 blows per minute. Sixteen to 20 blows are generally sufficient to compact the sand in an ordinary sized mold.

In operation, the stripping plate is placed over the pattern and the flask located. The latter is then filled with sand, the valve of the supply pipe admitting the air to the valve chest is opened and the series of operations will take place; that is, the air will raise the mold until the valve mechanism cuts off the supply, when the mold will descend rapidly until the central post strikes the jarring block. These operations will be automatically repeated until the supply of air is shut off. After the mold is rammed, lifted and turned over, the pattern is drawn out through the stripping plate, this part of the work being accomplished very much as in other types of molding machines.

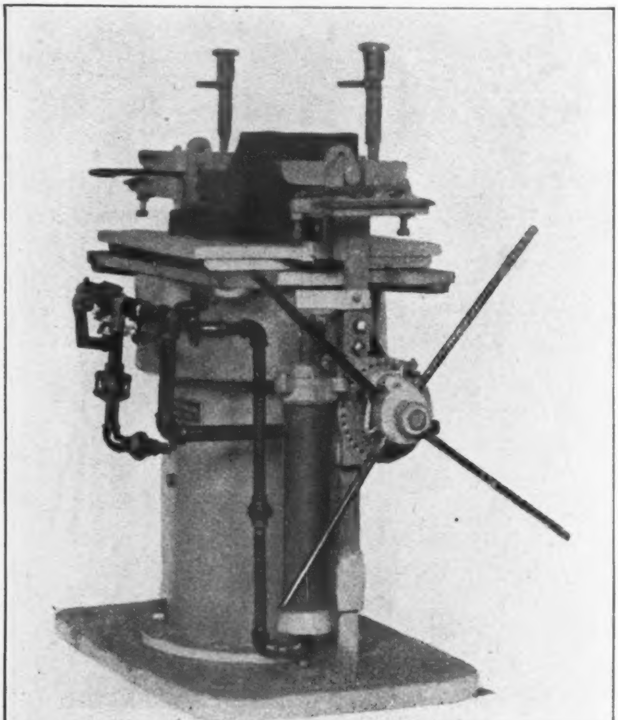


FIG. 3.—SIDE VIEW OF MOLDING MACHINE.

Inasmuch as the parts of the jarring mechanism are confined within the casing, and the cover with its flange always encloses the upper part of the casing in all positions, the machine is rendered practically sand tight, thus protecting the working parts. Patterns usually machine

molded flat can be molded upright on this machine. The sand is rammed hardest about the pattern and the mold is not so hard near the top, so that little or no venting is required.

The largest machines require a pressure of 60 pounds, while the smaller machines need proportionately less. The pattern shown in the illustration is 10 inches long and 8 inches high.—*The Iron Trade Review.*

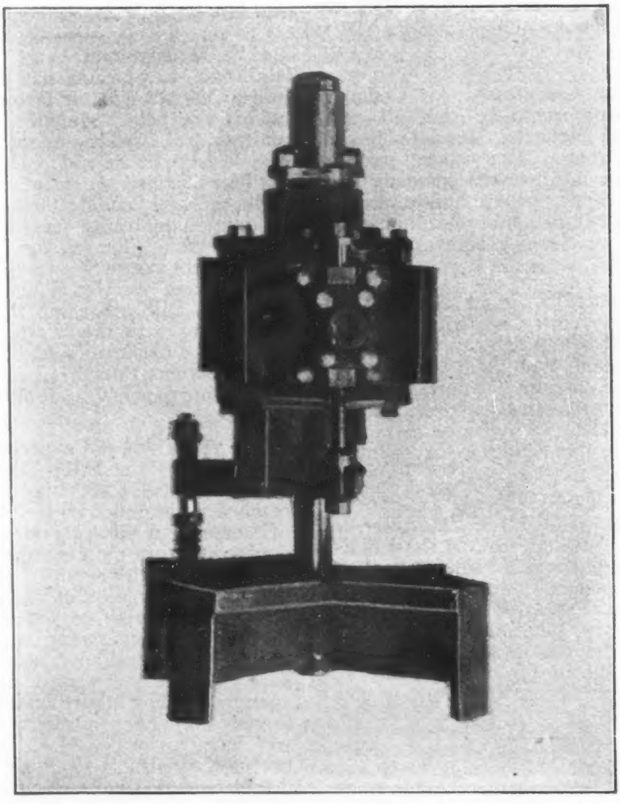


FIG. 4.—THE JARRING MECHANISM.

Notes.

James F. Burnam, Milton Lanier and C. C. Green, of Huntsville, Ala., have incorporated the Wear-Proof Pneumatic Tire Protector Company, with a capital of $2,000.

The International Automatic Air Brake Coupler Company was incorporated at Trenton, N. J., June 29, by L. B. Dailey, H. O. Coughlan and J. M. Mitchell. The capital is $3,000,000.

At the spring meeting of the Mining Institute of Scotland, held at Hamilton, Dr. A. Simon gave a description of the Champion coal cutter, and the members visited the Wishaw Coal Company's Colliery, near Motherwill.

Thomas A. McGlynn, business agent of the International Compressed Air Work-

ers, has closed an agreement with the United States Government to furnish forty men at Sabine Pass, Texas, to sink a caisson thirty miles from land in the Gulf of Mexico for a lighthouse.

Mr. William B. Armstrong, formerly manager of the New York business for the Chicago Pneumatic Tool Company, is now associated with the Ingersoll-Sergeant Drill Company, of 26 Cortlandt street, New York, and will look after the interests of the Pneumatic Tool Department.

The Oregon Compressed Air Company has been incorporated at Portland, Oregon, by H. C. Flanagan, Henri Labbe and Thos. N. Strong. The capital stock is $10,000. The object of the company is to acquire all rights, patent and otherwise, for compressed air and other household carpet and rug cleaning plants.

The Interborough Rapid Transit Company, of New York City, which operates all the elevated and subway lines on the Island of Manhattan, has just ordered Westinghouse motor compressors and governors and Westinghouse quick-action automatic brakes for the 200 new steel cars that they are building for operation in the subway.

J. J. Tynan and H. C. Mostiller, of Philadelphia, Pa., has secured the English patents for a pneumatic caulking tool. It consists of a pneumatic tool mounted on a form of carriage. A device is supplied for carrying the caulking material and permitting it to be fed as needed. There is also an attachment for automatically advancing the caulker as the work is completed.

Compressed air is beginning to be very useful in the best of the barber shops which are introducing it rapidly. The air does almost everything from the services of a brush after a haircut down to blowing the excessive powder off a customer's cheeks. The tubes connected with the main source of supply hang by every barber's chair now in the best equipped shops. The innovation is another luxury which, like most of those in these shops, did not have its origin here.—*New York Sun.*

At the Hazelwood creamery plant, at Portland, Oregon, compressed air is being used as a power to drive the cream through pipes to the churns. The air, after being thoroughly filtered and sterilized, is compressed by an electrically driven compressor. It is then admitted to the huge cream vats and forces the contents to the churns. This method is found economical, but its chief value lies in the fact that the cream is preserved from contact with the outside atmosphere preventing any possible contamination.

The Metropolitan West Side Elevated Railroad, of Chicago, has abandoned the use of the straight air brake on its trains, which are being equipped with multiple unit control, and has adopted in its stead the Westinghouse quick-action automatic air brake, as used in steam railway service, with the few modifications necessary for adaptation to trains operated by multiple unit control. This railroad has also made the Westinghouse motor-driven air compressor and electric pump governor its standard, and will equip the new cars it is building with the Westinghouse Traction Brake Company's latest type of compressor, which embodies a number of valuable improvements over previous forms.

The results of the experiments with oil fuel made by the Navy Department have been made public. Among the conclusions reached is the following: "While the use of steam as a spraying medium will undoubtedly prove most satisfactory for general purposes, the result of the tests show that the consumption of fuel oil cannot be forced to as great an extent with steam as the atomizing agent as when highly heated compressed air is used for this purpose. As the war ship is designed to be operated at short notice under the severest forced draught conditions, the question will have to be considered whether it is not more advisable to fit air burners that would be found most efficient for the day of battle rather than effect an installation of steam burners that are most desirable for general cruising."

The O'Rourke Engineering and Construction Company, which firm has the contract for building the Pennsylvania Railroad Tunnel under the Hudson River, has placed an order with the Ingersoll-Sergeant Drill Company for two central

compressed air power plants to be located at New York City and Weehawken, N. J. This installation will include eight 36-inch stroke Corliss Air Compressors having a total capacity of 25,000 cubic feet of free air. With the O'Rourke plant installed, the total number of Ingersoll-Sergeant Compressors supplying air for subaqueous tunnels in New York will be as follows:

Six Class "A" Straight Line Compressors.
Ten Corliss Duplex Compressors.
Three Class "H" Duplex Compressors.
Two Class "G" Duplex Compressors.

Something new in the line of an air compressor catalogue has just been issued by the Ingersoll-Sergeant Drill Company. It is more like a portfolio of views of standard machines and prominent installations, which are supplemented with descriptive tables of the standard sizes of compressors. The catalogue is finely printed and quite attractive. Among the illustrations is one of the new manufacturing plant of the Ingersoll-Sergeant Drill Company at Phillipsburg, N. J., the first time it has appeared in any of the publications of this company. Other interesting illustrations show the largest Corliss air compressor in the world, built for the Homestake Mining Company, at Lead, S. D., and types of the electrically-driven compressors, forty of which were built for the St. Louis (Mo.) Transit Company. While this catalogue No. 35 is complete in itself, it is really "Advance Sheets" of another catalogue, No. 36, which will appear in the course of a few months.

An English patent has recently been granted to H. H. Lake for a pneumatic apparatus for raising submerged objects from the sea. This submarine elevator consists of a series of elements constructed of impermeable fabric, leather, or india rubber, the form of which may be tubular, sack-shaped, and so forth, according to circumstances. These elements arranged side by side in several series are supplied by means of pipes coming from a central collector in communication, by means of pipes with accumulators, or compressors of air or gas, or with gas generators arranged upon the tug, or with boxes or other receptacles placed upon the supports of the elevators and adapted to contain ingredients capable of developing at a given moment the quantity of gas required for inflating the elements or placing them in tension. When the weight of the water displaced by the elements is greater than that of the object which it is desired to raise, and the supports of the elements have been connected to this object, this latter will be raised from the bottom and may be towed to any desired spot.

The Transvaal Chamber of Mines, Johannesburg, in October, 1902, offered three prizes, the first of £500 and gold medal, the second of £250, and the third of £100, for the three best practical suggestions and devices for obviating or minimizing the occurrence of miners' phthisis and suggestions and plans for combating the causes leading to the same. There were 229 competitors, and the judges in their report, dated April last, decided to award the full amount of the first prize and the gold medal to the atomizer submitted by Mr. Thomas J. Britten, which was found to lay 75 per cent. of the dust in the drive where it was tested, and which the judges state had been demonstrated as being the best practical suggestion submitted. The Judges express the opinion that the best means of combating the disease would be the use in drilling of a perfect water drill, together with the use of an atomizer for allaying the dust and gases during blasting and shoveling. The second prize was awarded the Leyner drill as being the best device submitted, and in the hope that it might stimulate manufacturers to further exertions in the direction of the production of a perfected water drill.

At the Calumet and Hecla copper mine, in the United States, is a peculiar air-compressing plant used for furnishing power and for ventilating the mine. A four-cylinder, triple-expansion vertical engine of 7,000 horse-power drives three horizontal cross compound or two-stage air compressors. It was at first intended to drive the main shaft from which the compressors are worked by means of a 25-foot rope wheel, but this was abandoned in favor of the steam engine. The cylinders are 29 inches, 51¼ inches, 58 inches, and 58 inches diameter, with a stroke of 7½ feet. The high-pressure and first low-pressure cylinders form one pair, and the

intermediate and second low-pressure cylinders form a second pair. To each piston rod is attached an extension rod which carries a crosshead, and from the crosshead rises a vertical connecting rod taking hold of the end of a triangular walking beam or rocking beam. The beam is 12 feet 6 inches long between centres and 4 feet 2 inches high, the lower limb being horizontal. From the top of this beam a horizontal connecting rod 20½ feet long, extends to the main crank shaft, which has cranks and connecting rods for the compressors. These are two beams and main connecting rods, one to each pair of steam cylinders, and one of the compressors is in line with the steam engine. The other half of the length of the main shaft has a compressor on each side. The compressors have cylinders 34½ inches by 60 inches and 54 inches by 60 inches. The air is compressed to 25 pounds in the first cylinder, with a temperature of 185 degrees. It then goes to a cooler which reduces the temperature to 60 degrees. In the second cylinder it is raised to 65 pounds pressure and 180 degrees, and then goes to an after-cooler which reduces the temperature to 80 degrees.—*Engineer* (Eng.)

Among the papers presented at the April conference of the Australasian Institute was one on "Power Transmission by Compressed Air," by Mr. R. W. Chapman (Adelaide University), which was read by Mr. A. G. Collison (Adelaide). The author, in the course of his paper, stated that as a means of transmitting power from the underground workings, and more particularly for the transmission of power to the actual working face, compressed air at present held the premier position. For the driving of rock drills it might be said to be without any serious competitor, although with the development of the electric drill it was likely that electricity would become a more formidable competitor in course of time. For this work it has been up till now the only suitable system available, and its incidental advantages in promoting ventilation at the working faces had to some extent compensated for the poor economy of the transmission. Great mechanical economy was not to be expected when the air was used without expansion as in the ordinary rock drill, and in an ordinary way considerably less than half the power generated by the steam at the surface was available at the face. Compressed air, however, was used for a variety of other purposes, such as driving winches underground and direct-acting pumps, where its incidental advantages were relatively of less importance, and where its mechanical economy was a greater factor in determining whether it should be used in place of steam, electricity, or other driving power. Unfortunately, from a mechanical point of view, the use of compressed air underground was subject to two great disadvantages. It generally had to drive a motor, in which the compressed air was used either non-expansively or with very little expansion; and the use of a reheater near the motor, which was such an important factor in an economical system of air transmission, was generally attended with formidable difficulties underground. These unfavorable conditions both very seriously affected the efficiency of the system.

When liquid air was brought into prominence by the excellent work done by Mr. Tripler there were all sorts of claims made for it, some of them being advanced by scientific men who went so far as to predict that by means of liquid air our rules governing the conservation of energy were likely to be upset. Liquid air companies were organized and "promoted" in the usual way, very much to the disadvantage of the stockholders and to the injury of the subject. Liquid air has never been much more than an interesting, scientific experiment. Of late considerable interest has been shown by audiences at Proctor's Twenty-third Street Theatre in the performance of a Mr. Joseph Yarrick with his "Magic Kettle." This has been advertised as the most remarkable scientific achievement ever presented. That the exhibition of Mr. Yarrick and his "Magic Kettle" should have continued into the fifth week at a theatre which changes its programme weekly is an evidence of the popular interest in this performance. The "Magic Kettle" is nothing more than a common kettle filled with liquid air, but Mr. Yarrick, unlike the promoter of the liquid air company, gives his audience value received for his clever deception in that he produces curious and interesting results, mystifying the audience by what might be called scientific jugglery, and all for the small price of a seat at Proctor's. The curtain rises with a kettle filled with

liquid air "boiling" on the top of what appears to be a common oil stove. To the audience this is nothing more or less than a kettle boiling, but Mr. Yarrick pours the contents into a common hat, washes a handkerchief in it, uses it to fry an egg to the hardness of a steel plate, over a piece of ice, makes ice cream through the use of the contents of the kettle, and ends up with an exhibition of Vesuvius in eruption, results logically due to the use of liquid air and none the less interesting, because what is presented as "magic" is really nothing but an exhibition of results due to natural laws which are so little understood by the public. This exhibition is not only a good show, but it is also a good schooling.

Some interesting information regarding the installation of pneumatic tube systems was contained in the annual report of President W. E. L. Dillaway, presented at the annual meeting of the American Pneumatic Service Sompany, recently held at Wilmington, Del.

The report says, in part: "Our business for the last year has been satisfactory and fully up to the expectation of your directors. The work of constructing the mail service systems under existing contracts with the United States Government is now practically completed. In Boston the entire system has been in successful operation since September last, and has brought about great improvements in the postal service. In our last report it was stated that our contract with the United States Government for the Boston system provided for an additional annual rental of $21,375 as soon as the appropriation had been increased. Congress at the last session made special provision for this amount, and beginning with July 1, 1904, our rental for this system will not be less than $101,224 per year.

"In St. Louis the system has been completed, with the exception of the line crossing the Mississippi river over the Eads Bridge to East St. Louis. The system as completed will be in operation in a few days, from which time rental from the United States Government will begin. In Chicago our system is rapidly approaching completion, and will be in operation on or about July 1 next, at which time rental begins. Extensions to the systems in Boston, Chicago and St. Louis are already under consideration, and it is anticipated that another year will find the service adopted for other cities. We are about closing other contracts, concerning which we consider it inadvisable to more than refer to, at this time.

"The business of our subsidiary companies carrying on the small tube and store service business, has been satisfactory, and is steadily increasing in volume and diversity. The parcel delivery business has increased nearly 40 per cent. over the preceding year, and we hope to soon acquire all of this kind of business for the city of Boston."

In discussing the widening use of compressed air in shop and foundry, Professor J. J. Flather, in *Cassier's Magazine*, says:

"In most cases no attempt has been made to use the air efficiently; its great convenience and the economy produced by its displacement of hand labor have until recently been accepted as sufficient, and greater economies have not been sought.

"In the matter of compression we still occasionally find very inefficient pumps in use, but manufacturers generally have learned that it pays to use high grade, economical compressors. The greatest loss is that in the air motor itself. In a large number of cases it is impracticable, or, at most, inconvenient to employ reheaters, and we find very generally that the air is used at normal temperatures for the various purposes to which it is applied.

"To obtain the most satisfactory results, the air must be used expansively; but usually where the demand for power is intermittent, no attempt has been made to reheat the air, and as a result the combined efficiency of compressor and motor is quite low, varying in general from 20 to 50 per cent. While low working pressures are more efficient than high, the use of such pressures would demand larger and heavier motors and other apparatus which is undesirable. The advantages of higher pressures in reducing cost of transmission are also well recognized, and the present tendency is to use air at 100 to 150 pounds instead of the 60 or 70 pounds of a few years ago.

"By reheating the air to a temperature of about 300 degrees Fahrenheit, which may often be accomplished at small expense, the efficiency is greatly increased; in some cases the increase has been found

to be as high at 80 per cent. While the lower pressures are yet more efficient, the loss due to higher compression is not serious.

"If air be used without expansion, there is a material loss in efficiency; but, on the other hand, if it be used expansively without reheating, trouble may be experienced from drop in temperature below the freezing point. With moisture present, this drop will cause the formation of ice, which may clog the passages if proper precautions are not taken to prevent it. The low temperature will not in itself cause trouble; if, therefore, the moisture which the compressed air holds in suspension be allowed to settle in a receiving tank, placed near the motor or other air apparatus, and frequently drained, trouble from this cause will be largely avoided.

"While it may be impracticable to reheat the air in certain cases, yet there are many situations where a study of means to overcome the losses referred to would result in marked economies."

In an article entitled "Machinery Improvements in the Transvaal Mines," published in *Engineering* (Eng.), the subject of rock drills and air compressors is discussed. It says in part: "Progress is most marked in the more extended use of rock drills, and in improved methods of handling the ore and waste products both in the mine and on the surface. Thus, rock drills are being employed over small stoping widths where previously hand-drilling was the practice; thus, in a stope only 31 inches wide a 2½-inch drill is at work doing four 5-foot holes per shift, leading to the breaking up of three tons of rock per drill. The cost, however, is said to be greater than with hand drilling. The 1,340 drills at work in the Transvaal in June of last year, according to the yearly report of the Government mining engineer, Mr. W. Wybergh, Commissioner of Mines, have, as a rule, 3⅛-inch to 3¼-inch tools, and each use 3 horse-power, although experience has shown that the prime mover requires to develop about 12 horse-power per drill, the loss in transmission being considerable. These drills cost about 37*l*. each, and the monthly outlay for repairs is approximately 5*l*. One of the important desiderata of the industry at the moment is a satisfactory detachable bit for these drills, as the carrying of the whole tool of 15 pound weight to the surface for sharpening, etc., involves a large amount of labor. As each machine needs 20 drills per shift, an installation of 60 machines necessitates the transport up or down the shaft of nearly 18 tons of material, and in view of the enormous depths to which work is now being carried, this is a serious item. As to the 157 air compressors, of a collective power of 46,090 horses, in use in the colony, vertical machines are not favored, the horizontal two-stage compression type being almost universal. A machine which has become almost a standard is one suitable for 35 drills, running at 68 revolutions per minute, and indicating 450 horse-power. But latterly there has been a tendency to go in for larger units, suitable for 75 drills and indicating 900 horse-power. An interesting departure of the past year is the installation of a turbo air compressor at one of the mines, but no results are yet forthcoming as to its working. The air, as a rule, leaves compressors at a temperature of about 300 degrees Fahrenheit, and at 80 pounds maximum pressure. The sectional area of the steel pipe-line into the mine is generally 1 square inch per drill, and it is made up in lengths of 15 feet to 18 feet, having screwed connections, with flanges at each third or fourth joint. The air is not reheated, except where used for pumps or hoists, and then the practice gives marked efficiency."

The jury of the Transvaal Chamber of Mines has decided that of the several hundred inventions submitted for its consideration as a means of preventing the injury to health which the mine dust causes, that devised by Mr. T. J. Britten is the most satisfactory, and he has been awarded the first prize. No doubt it is in regard to superiority of design in detail that the award has been bestowed, since in principle the method adopted of utilizing the compressed air required for the drills to vaporize water is the only one which has had the serious consideration of practical miners. Respirators are recognized not only as liable to rapid deterioration in fit and wear, but above all as quite impossible of enforcement, and naturally the less moisture required for watering the better. The appliances used at Dolcoath appear to be almost identical with the means approved by the Transvaal

Chamber of Mines. In the Cornish mine a small nozzle of the ordinary garden hose type is used, which ejects water into the mouth of the hole with a rotating movement, which scatters the jet into a spray, while the late manager of the Wolhuter believes that more complete saturation is obtained by the use of a regular atomizer. In regard to the dust from shot firing which affects a larger number of men, the practice is equally similar. The plan which has been found very effective at Dolcoath is that of Mr. William James, and is shortly as follows: At the mouth of the level a piece of 6-inch iron pipe, provided with a side-tap, is let into the ordinary 2-inch iron pipe for carrying the compressed air to the drill. Before blasting this is filled with water through the side-tap from a cistern after the compressed air has been turned off. Immediately after the blast the compressed air is suddenly turned on. The water is thus driven along the pipe, and a mixture of finely divided water and air is discharged from the open end, which is pointed toward the face which has just been blasted. A ventilating pipe is also used where the level or rise is more than a few feet from the shaft, the compressed air being further used to extract the air after the blast. This ancillary arrangement will probably be even more desirable in the Transvaal than in Cornwall, where the more frequent shot firing leaves more CO to be got rid of. The main difficulty experienced in all questions relating to the health and safety of mine employes lies not in devising safety appliances, but in insuring their use. The spraying system is a very old friend at Dolcoath, having been in use quite thirty years ago, according to the manager, and given up owing to the opposition of the men. What is really required are mine regulations and active inspection. Meanwhile, as matters stand now, there is a great opportunity for the enterprising machinery makers to obtain a careful trial for any specialties they may have for dealing with this serious problem.—*Mining Journal* (Eng.)

A system of low pressure pneumatic signals is being given a trial by the Great Central Railway Company at Manchester, England. A description of the old method and a comparison with the new were published in the *Manchester Guardian*.

Under the old method some of the levers had attached to them 800, 900, or even 1,000 yards of heavy wire. So that at times it was as much as a man could do, by using the utmost exertion, to bring a long-distance signal into the desired position. The low-pressure pneumatic system can be contained in a much smaller cabin than a manual apparatus with the same number of levers. Therefore less exercise on the part of the signalman is necessary, and, indeed, the work of two men may in some boxes be done with ease by one. The levers themselves are quite easy to move, a very slight pressure is sufficient to set the mechanism in motion. Then the pneumatic tubes by means of which the signals are operated are placed underground, and so are rendered harmless, while at the same time they are protected against injury.

The low-pressure pneumatic system is itself of a fairly simple character. The levers, together with the necessary interlocking plant (this latter, by the way, in the case of the manual system is placed under the signal-box), are all contained in a compact frame in the centre of the cabin. When the signalman wishes to lower a signal he pulls down his lever for a distance of two inches only. This slight depression of the lever results in the opening of a valve, which lets in atmospheric pressure at 15 pounds to the square inch. The air passes through the operating pipe to the signal, which is worked by means of a cylinder. As soon as the signal arm is released the air comes back through the communicating pipe to the signal box and completes the movement of the lever initiated by the signalman. That is to say, the lever is further depressed automatically, and the signalman is thereby assured that the signal arm has dropped and that the switches have been moved home to the stock rail. In connection with this pneumatic system there is provided a track circuit in sections. The rails are electrified by low tension to about seven volts. When the train has passed the signal the track circuit operates the valve at the foot of the signal and automatically replaces the signal. At the same time it replaces the lever in the signal cabin in its original position. The signalman does not, in fact, once touch the lever after he has initiated the movement by half pulling the lever in the first instance. The experiment is being carried out on the portion of the line lying between Ardwick and Newton. There were 16 signal boxes on

this stretch of railway, but the company will dispense with four of these and concentrate the work in the remaining twelve. The number of levers is reduced from 727 to 366, and, in addition, there will be a saving of 178 signal-arms.

Considerable attention has been attracted to rail laying equipment which has been tried with success on one of the Philadelphia street railway lines. Air compressors are placed on wagons and are driven by electric motors which get their current from the trolley wires. It is brought down to the machine by a wire attached to a piece of bamboo, in shape and size very much like a large fishing pole, the wire being bent in the form of a hook at the upper end, so that it may be hung on the trolley wire or taken off at pleasure.

When the old rails have been removed the trench is dug to the required depth, the temporary cross-ties are put in and the new rails placed upon them. The first operation is then the cleaning of the ends of the rails of dirt and rust. This is done with a sand blast supplied through tubing from a wagon. It cuts everything off of the rail until the metal shines forth brightly. The operation makes such a cloud of fine sand and metal dust that the man who operates the blast is compelled to wear a hood something like a diver's helmet, with a fine-meshed screen in it for ventilation. What other workmen there may be in the immediate vicinity of the operation generally keep their mouths and noses covered with handkerchiefs.

After the sand blast comes the wagon with the reaming machine, run by compressed air. Holes have already been drilled or punched in both rails and fishplates, but the reaming enlarges the holes to the size of the bolts or rivets to be used. The wagon with the machinery for bolting or riveting the fishplates comes next. It has a crane that holds the bolting machine in position, and at the back small coal fires, with electric blowers, for heating the rivets.

The fishplates are of such form that after being bolted to the rail some space is left between rail and plate. The eyes of the fishplate are stopped with clay and pieces of canvas, and the whole joint is heated with a flame furnished by a combination of coal oil and compressed air supplied from another wagon. On the same wagon are pots full of melted metal heated in the same way, and this is run through funnels into the space between rail and fishplates on both sides. This makes the electric bond whereby the current passes along the ground circuit from one rail to the other.

When the rails are bolted and connected they are adjusted as to gauge or distance between them. The foundation on which they rest is a bed of concrete extending from rail to rail, the cross-ties being removed. At every six feet is an iron yoke extending downward from each rail into the body of the concrete, and the gauge is further maintained by tie rods. The concrete extends up to above the bottom flange of the rail and over it is put the paving.

In the method described each of the various wagons has its separate crew, the work required being of an expert nature and with the helpers, the men who dig the ditches, the gaugers, the layers of the concrete and the layers of the pavement, the total number of workmen on the job is very large.

INDEX.

U.S. PATENTS GRANTED JUNE, 1904.

Specially prepared for COMPRESSED AIR.

761,651. AIR-BRAKE. John W. Bingley, Watertown, N. Y., assignor to New York Air Brake Company, a Corporation of New Jersey. Filed Oct. 16, 1903. Serial No. 177,317.

761,683. AIR-BRAKE. John P. Kelly, Watertown, N. Y., assignor to New York Air Brake Company, a Corporation of New Jersey. Filed Nov. 27, 1903. Serial No. 182,836.

761,692. CAR-BRAKE. William C. Mitchell, and Mark Cummins, Trafford Park, England, assignors to The Westinghouse Air Brake Company, Pittsburg, Pa., a Corporation of Pennsylvania. Filed Oct. 13, 1903. Serial No. 176,846.

761,777. PNEUMATIC TIRE. Carl W. Maxon, West Bay City, Mich., assignor of two-thirds to Stanley A. Bush, South Arm, Mich., and Walter L. French, East Jordan, Mich. Filed Nov. 2, 1903. Serial No. 179,610.

761,790. PNEUMATIC ELEVATOR. George F. Steedman, St. Louis, Mo. Filed Feb. 9, 1901. Serial No. 46,651.

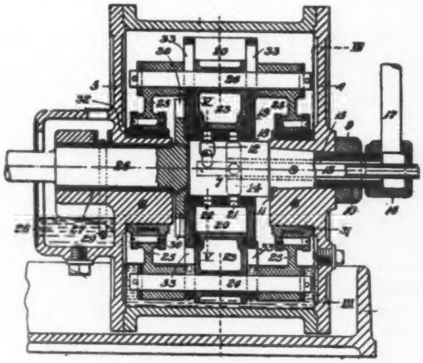
The combination with a hoisting-cylinder, of a valve for controlling the admission and exhaust of pressure to and from said cylinder, said valve including a casing having a chamber at one end into which the inlet-pipe leads, a chamber at the opposite end from which the out-let pipe leads, an intermediate chamber having a graded port which communicates with the inlet or exhaust chambers, and a chamber in communication with an auxiliary valve; substantially as described.

761,847. TIRE. John Millar, Kearney, N. J., assignor of one-half to Henry Willoughby, Jr., Kearney, N. J. Filed Mar. 7, 1904. Serial No. 197,015.

762,025. CONTROLLING-VALVE FOR AIR-BRAKE SYSTEMS. Edward Cheshire, Milwaukee, Wis. Filed Nov. 11, 1903. Serial No. 180,670.

762,127. TRAIN-PIPE COUPLING. Guy L. Bonham, Dorranceton, Pa. Filed Feb. 26, 1904. Serial No. 195,466.

761,933. ROTARY AIR-COMPRESSOR. Gustav A. F. Ahlberg, Pittsburg, Pa. Filed Sept. 26, 1903. Serial No. 174,729.



A rotary air-compressor comprising a base having side frames or heads, a stationary ported bearing or valve supported in an opening in one of said frames, a shaft having a bearing in an opening in the opposite side frame in alinement with said valve, a cylinder-frame secured to said shaft and carrying a plurality of cylinders rotatably mounted on said stationary valve, the cylinders having ports co-operating with those of said valve, pistons for said cylinders, an eccentric-bearing supported on each of said side frames, and means operating on said eccentric-bearings for reciprocating said pistons.

762,140. APPARATUS FOR EXHAUSTING THE AIR FROM CANS. William E. W. Cates, Bristol, England, assignor to the Vacuum Tin Syndicate, Limited, Bristol, England. Filed Oct. 3, 1902. Serial No. 125,821.

762,177. AIR-BRAKE SYSTEM. John Loftus, Albany, N. Y., assignor of one-half to Stanton Redick, Albany, N. Y. Filed Sept. 22, 1903. Serial No. 174,200.

762,282. FLUID-PRESSURE BRAKE APPARATUS. Murray Corrington, New York, N. Y. Filed Sept. 28, 1903. Serial No. 174,946.

762,368. ELASTIC-FLUID TURBINE. Lida Wilson, Glasgow, Scotland. Filed Jan. 30, 1904. Serial No. 191,340.

The combination with an elastic-fluid turbine having concentric passages for the axial movement of the motive fluid through the turbine, and multiple sets of radial rotatable blades to drive the shaft passing through both passages, of means

applied to the exhaust-exits adapted to retain the motive fluid at initial pressure and temperature in either of the concentric passages as and when desired.

762,431. SUCTION APPARATUS FOR PAPER-MACHINES. Patrick C. McGrath, Glens Falls, N. Y. Filed June 11, 1903. Serial No. 161,065.

762,469. MACHINE FOR GRINDING THE PACKING-RINGS AND SLIDE-VALVES IN AIR-BRAKE TRIPLES AND ENGINEERS' VALVES. George M. Curran, Middletown, N. Y. Filed July 6, 1903. Serial No. 164,375.

762,501. PNEUMATIC TIRE. Georges Steinberg, Paris, France. Filed Apr. 1, 1903. Serial No. 150,528.

762,615. AIR-EXPANDING WATER-ELEVATOR. Andrew Bye, Butte, Mont. Filed July 24, 1902. Serial No. 116,803.

A water-elevator, a receptacle provided with a water inlet and outlet and an air-inlet, an air-chest mounted above the receptacle and communicating with said air-inlet and provided with a bracket, a slide-valve and an oscillating valve for controlling the passage of air through the chest, the outer end of the stem of the oscillating valve being mounted in said bracket, a lever pivotally mounted on the side of the bracket, a link for connecting one end of the lever with said valve-stem, a rod connected with the other end of the lever, and a float in the receptacle connected with said rod.

762,667. FLEXIBLE PIPE-JOINT. Charles H. Weaver and Lemuel H. Houghton, Elkhart, Ind., assignors of one-fifth to Charles J. Donahue, Cleveland, Ohio, and Grant H. Houghton, Chicago, Ill. Filed June 6, 1903. Serial No. 160,310.

A flexible pipe-joint, the combination of two joint elements, a flanged member connected with one of such elements, a packing-ring intermediate of such flanged member and the other element, and a coil spring located within both of such elements, engaging the same, and tending to separate their opposing faces.

762,721. REVERSING-VALVE. William H. Hume, Buffalo, N. Y. Filed May 29, 1902. Renewed July 3, 1903. Serial No. 164,248.

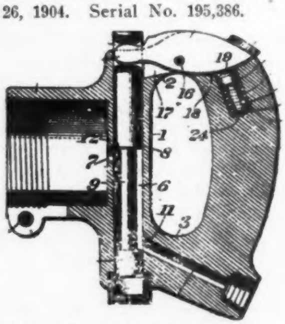
A reversing-valve consisting of a chamber having separate open compartments arranged therein and an opening in the top thereof above each compartment, said compartments being in communication with the furnace, an inlet-passage for gas and air supported within and depending from one of the aforesaid openings into the open compartment therebeneath, an exit-passage for spent gas removably supported within and depending from the other of the aforesaid openings into the open compartment therebeneath, water in each of the compartments for alternate action upon the said depending passages to regulate and control the flow of gas and air and the discharge of spent gas, and means for adding water and varying the level thereof in the compartments of the valve.

762,740. PNEUMATIC TIRE. Thomas Midgley, Columbus, Ohio. Filed Mar. 23, 1904. Serial No. 199,515.

762,767. FLUID-PRESSURE REGULATOR. James W. Scott, Colorado Springs, Colo. Filed July 28, 1903. Serial No. 167,323.

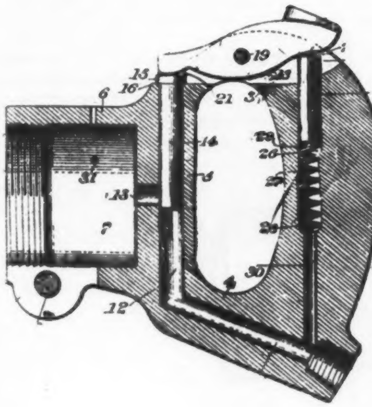
A fluid-pressure regulator having a diaphragm-casting, a diaphragm therein, a diaphragm-support for engagement by one side of the diaphragm, the outer end of the support being fulcrumed, and a ball-bearing for the inner end of the support, as set forth.

762,860. HANDLE FOR PNEUMATIC TOOLS. William H. Keller, Philadelphia, Pa. Filed Feb. 26, 1904. Serial No. 195,386.



A device of the character named, a body, a grasping portion, a neck joining said grasping portion to said body, a pressure-supply duct outside of said grasping portion and leading through said neck and said body, a port discharging from said body, a throttle-valve located normally in the upper portion of said body outside of the handle and its grasping portion, extending transversely to said body and adapted to control said port, a neck depending from said throttle-valve, a head attached to said neck and normally always below said pressure-supply duct and a manually-operated lever for actuating said throttle-valve.

762,861. HANDLE FOR PNEUMATIC TOOLS. William H. Keller, Philadelphia, Pa. Filed Mar. 5, 1904. Serial No. 196,654.



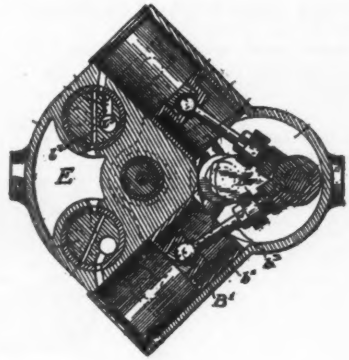
A device of the character named, a handle, a main pressure-supply duct located wholly exterior to the grasping portion thereof, a throttle-valve also located wholly exterior to said grasping portion and having live-air pressure acting on it, said valve being arranged to close by gravity when in normal position and when the supply of motive fluid is disconnected from said tool, and means for operating said throttle-valve.

762,917. PNEUMATIC STACKER. Ole L. Larson, Minneapolis, Minn., assignor to Fosston Wind Stacker Company, Minneapolis, Minn., a corporation of Minnesota. Filed June 12, 1903. Serial No. 161,150.

762,933. THROTTLE-VALVE FOR PORTABLE PNEUMATIC MOTORS. Reinhold A. Norling, Aurora, Ill., assignor to Aurora Automatic Machinery Company, Aurora, Ill., a Corporation of Illinois. Filed Nov. 19, 1903. Serial No. 181,804.

The combination with a supply-pipe, of a rotative throttle-valve embracing an endwise-facing valve-seat provided with a port, a rotative valve-disk which rests in contact with and is adapted to turn on said valve-seat and is also provided with a port, and a rotative tubular handle on the supply-pipe which is connected with and adapted to give rotative movement to said valve-disk, the ports in the valve seat and disk being arranged eccentrically to the axis of rotation of said disk.

762,932. PORTABLE PNEUMATIC MOTOR. Reinhold A. Norling, Aurora, Ill., assignor to Aurora Automatic Machinery Company, Aurora, Ill., a Corporation of Illinois. Filed Sept. 21, 1903. Serial No. 173,950.



A portable pneumatic motor comprising a plurality of sets of power-cylinders, arranged at an angle to each other, pistons in said cylinders, a crank-shaft with which the said pistons are connected, the cylinders of each set being parallel with each other and having their central axes in a plane which is radial with respect to the axis of the crank-shaft, valves for said cylinders embracing rotative valve-plugs the central axis of which are parallel with the axis of the crank-shaft and each of which is common to all of the cylinders of one set of cylinders, and operative connections between the crank-shaft and said valve-plug for actuating the latter.

762,995. AIR-BRAKE. James H. Graham and Edward M. Potts, Seattle, Wash. Filed May 11, 1903. Serial No. 156,583.

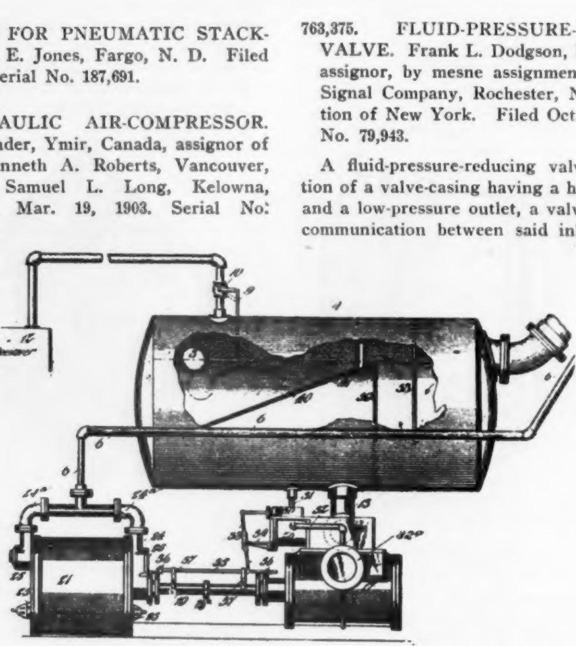
763,046. PNEUMATIC SYSTEM OF MOTOR CONTROL. Fred B. Corey, Schenectady, N. Y., assignor to General Electric Company, a Corporation of New York. Filed Dec. 5, 1902. Serial No. 133,979.

763,047. MOTOR-CONTROL SYSTEM. Fred B. Corey, Schenectady, N. Y., assignor to General Electric Company, a Corporation of New York. Filed Dec. 5, 1902. Serial No. 133,980.

763,071. MOTOR-CONTROL SYSTEM. Charles L. Perry, Schenectady, N. Y., assignor to General Electric Company, a Corporation of New York. Filed July 22, 1903. Serial No. 166,577.

763,101. CHUTE FOR PNEUMATIC STACKERS. William E. Jones, Fargo, N. D. Filed Jan. 4, 1904. Serial No. 187,691.

763,239. HYDRAULIC AIR-COMPRESSOR. John H. Alexander, Ymir, Canada, assignor of one-half to Kenneth A. Roberts, Vancouver, Canada, and Samuel L. Long, Kelowna, Canada. Filed Mar. 19, 1903. Serial No. 148,548.



The combination in an air-compressing apparatus of a pipe for conducting a falling column of water under due pressure, and having an outlet to atmosphere, a separating-tank into which said pipe discharges, a storage-tank and a supplemental air-compressing mechanism, comprising a hydraulic cylinder having a piston arranged for operation by the water discharged under pressure from the separating-tank, an air cylinder and piston, the air-piston being connected with said piston of the hydraulic cylinder for operation thereby, and a pipe 6 connecting the supplemental air-compressing mechanism and the said vertical pipe leading to the separating-tank, whereby the air compressed by said supplemental mechanism is conveyed into said pipe 6 and thus into the separating-tank; substantially as shown and described.

763,311. AIR-BRAKE. William O. Mundy, St. Louis, Mo. Filed Feb. 6, 1904. Serial No. 192,458.

763,312. AIR-BRAKE. William O. Mundy, St. Louis, Mo. Filed Feb. 6, 1904. Serial No. 192,458½.

763,346. SAFETY ATTACHMENT FOR CAR-BRAKES. John B. Wright, Greensboro, N. C. Filed Sept. 17, 1903. Serial No. 173,599.

763,375. FLUID-PRESSURE-REDUCING VALVE. Frank L. Dodgson, Rochester, N. Y., assignor, by mesne assignments, to Pneumatic Signal Company, Rochester, N. Y., a Corporation of New York. Filed Oct. 25, 1901. Serial No. 79,943.

A fluid-pressure-reducing valve, the combination of a valve-casing having a high-pressure inlet and a low-pressure outlet, a valve controlling the communication between said inlet and outlet, a spring for closing said valve, a stronger spring for opening said valve, means for regulating the tension of the latter spring, a diaphragm-chamber in said casing, a flexible diaphragm adapted to act upon said stronger spring, a diaphragm-plate, means for guiding said diaphragm-plate, to move only in the line of movement of said valve, and a port connection from said low-pressure outlet to said diaphragm-chamber, whereby the valve closes when pressure in the outlet upon the diaphragm is sufficient to compress the stronger spring, and the valve is opened by said stronger spring when pressure in the outlet falls below a predetermined pressure, substantially as described.

763,389. PNEUMATIC COTTON-PICKER. Rudolph Getzlaff, Amsterdam, Ga. Filed Apr. 13, 1904. Serial No. 203,008.

763,539. PNEUMATIC-TIRE COVERING. George F. Brown, Hurstville, New South Wales, Australia. Filed Nov. 25, 1902. Serial No. 132,797.

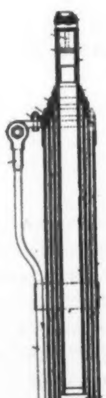
763,540. RAILWAY-SIGNAL. John P. Coleman, Edgewood, Pa., assignor to the Union Switch and Signal Company, Swissvale, Pa., a Corporation of Pennsylvania. Filed Feb. 2, 1903. Serial No. 141,468.

763,686. FLUID-SWITCH. Nelson H. Medbery, Milwaukee, Wis. Filed Aug. 21, 1903. Serial No. 170,312.

A fluid-switch the combination of a case having a constant and a plurality of alternating outside fluid connections, a valve arranged to change the flow of fluid from one alternating connection to another, a valve-actuating device, a locking device for holding said valve in a given position, and an automatic trip adapted to release said locking device and permit the shifting of said valve to another position, substantially as described.

763,834. AIR-BRAKE APPARATUS. Oliver A. Alexander, Philadelphia, Pa. Filed Sept. 10, 1903. Serial No. 172,667.

763,887. PNEUMATIC RIVET-HOLDER. Alonzo L. Hastings, Allegheny, Pa., assignor of one-half to Pressed Steel Car Company, Pittsburg, Pa. Filed Jan. 8, 1904. Serial No. 188,244.



A pneumatic rivet-holder comprising a casing containing a series of telescopic plungers having rear heads, at least a part of which are provided with constricted openings, said casing having a fluid-inlet in the rear of the plungers, and a rivet-fitting secured to the projecting end of the innermost cylinder; substantially as described.